US009323103B2

(12) **United States Patent**
Mori et al.

(10) **Patent No.:** **US 9,323,103 B2**
(45) **Date of Patent:** **Apr. 26, 2016**

(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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(73) Assignee: **Sharp Kabushiki Kaisha**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 137 days.

(21) Appl. No.: **13/808,161**

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(86) PCT No.: **PCT/JP2011/054991**
§ 371 (c)(1), (2), (4) Date: **Jan. 3, 2013**

(87) PCT Pub. No.: **WO2012/005022**
PCT Pub. Date: **Jan. 12, 2012**

(65) **Prior Publication Data**

US 2013/0113847 A1 May 9, 2013

(30) **Foreign Application Priority Data**

Jul. 9, 2010 (JP) 2010-157160

(51) **Int. Cl.**
H04N 5/202 (2006.01)
G02F 1/1335 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .... ***G02F 1/133603*** (2013.01); ***G02F 1/133514*** (2013.01); ***G09G 3/3413*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC G02F 1/1335; G09G 5/10; G09G 3/32; G09G 5/00; G09G 3/18; G09G 3/36; G09G 5/02; H04N 17/02; H04N 9/12; H04N 5/202; H01L 21/00
USPC 345/82, 88, 214, 690, 691, 694; 348/189, 674; 349/109; 438/7
See application file for complete search history.

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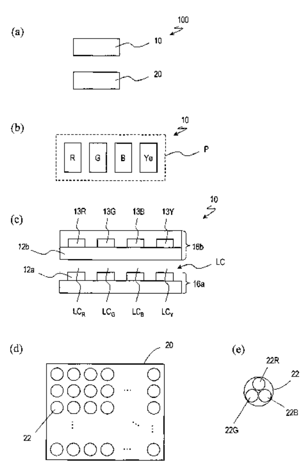
Primary Examiner — Nicholas Lee
Assistant Examiner — Abdul-Samad A Adediran
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

The liquid crystal display device (**100**) of the present invention includes a liquid crystal panel (**10**) having a plurality of pixels (P), and a backlight (**20**) having at least one light source (**22**) that emits light to the liquid crystal panel (**10**). Each of the plurality of pixels (P) includes four or more sub-pixels (R, G, B, Ye), and the light source unit (**22**) includes a red light source (**22**R), a green light source (**22**G), and a blue light source (**22**B). According to the present invention, a liquid crystal display device which can perform display of wide color reproduction range with low power consumption is provided.

17 Claims, 23 Drawing Sheets



(51) **Int. Cl.**
G09G 3/34 (2006.01)
G09G 3/36 (2006.01)

(52) **U.S. Cl.**
CPC ***G09G3/3607*** (2013.01); ***H04N 5/202*** (2013.01); *G02F 2201/52* (2013.01); *G09G 3/3426* (2013.01); *G09G 2300/0452* (2013.01)

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JP	2008-537179	A	9/2008
JP	2009-538442	A	11/2009
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FIG. 1

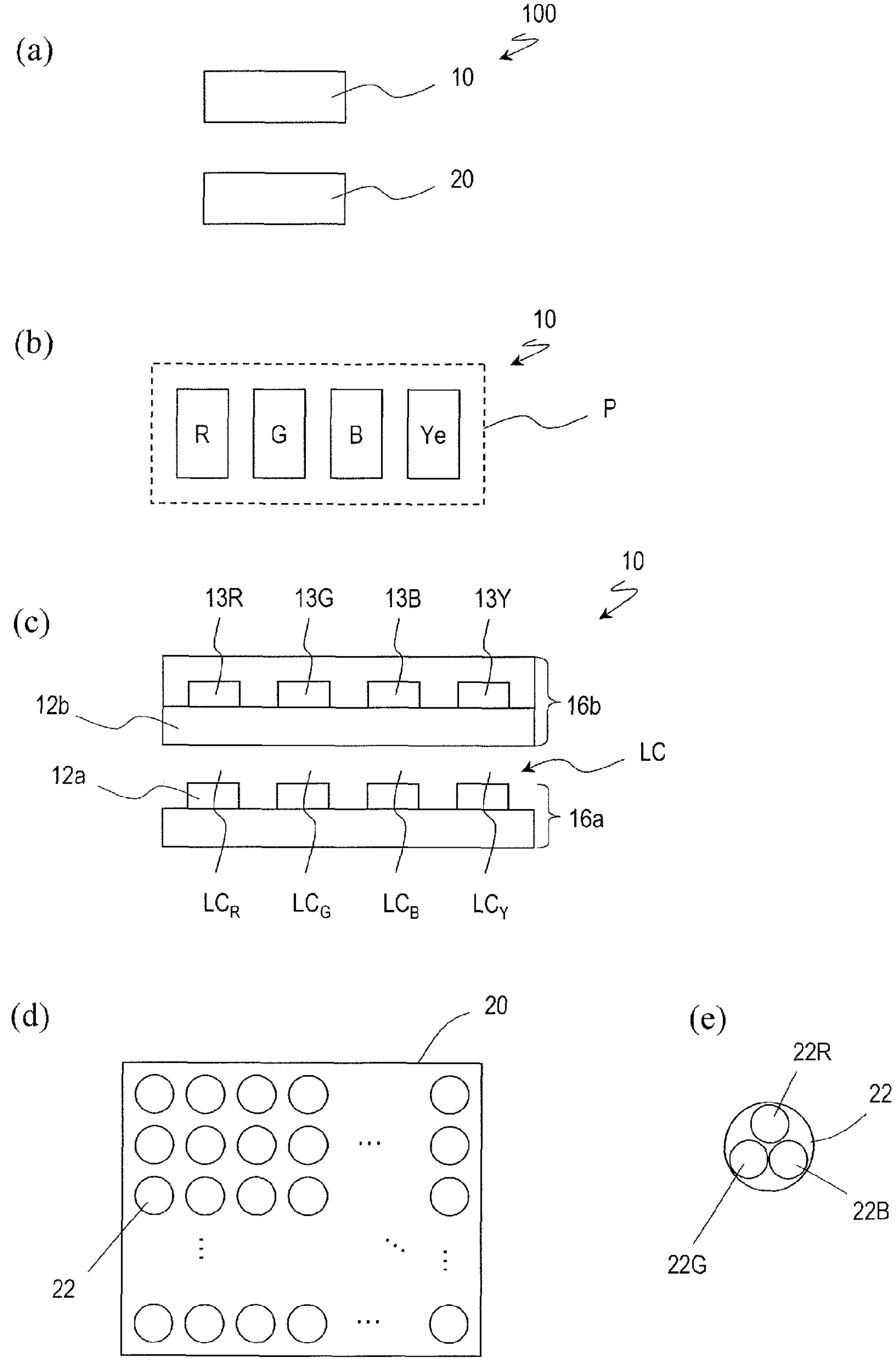

(a)
100
10
20
(b)
10
R
G
B
Ye
P
(c)
10
13R
13G
13B
13Y
12b
16b
LC
12a
16a
LC_R
LC_G
LC_B
LC_Y
(d)
20
22
(e)
22R
22
22B
22G

FIG.2

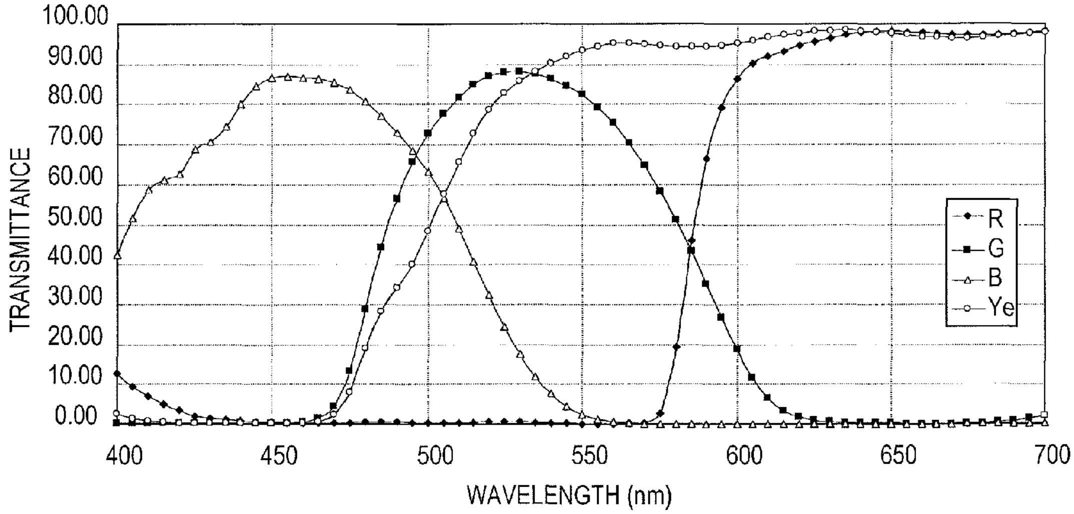


FIG.3

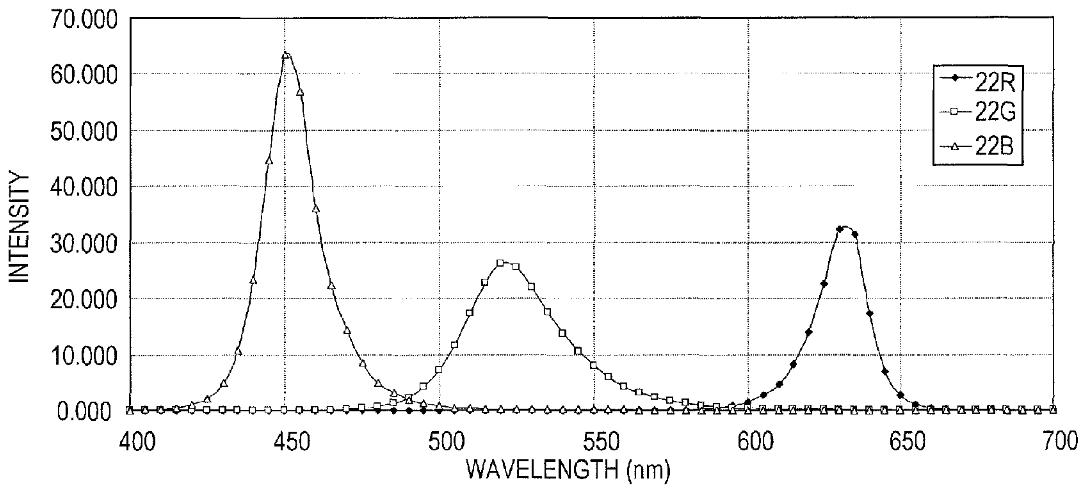


FIG.4

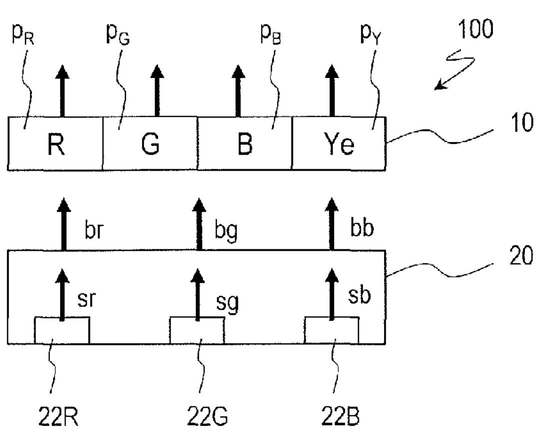
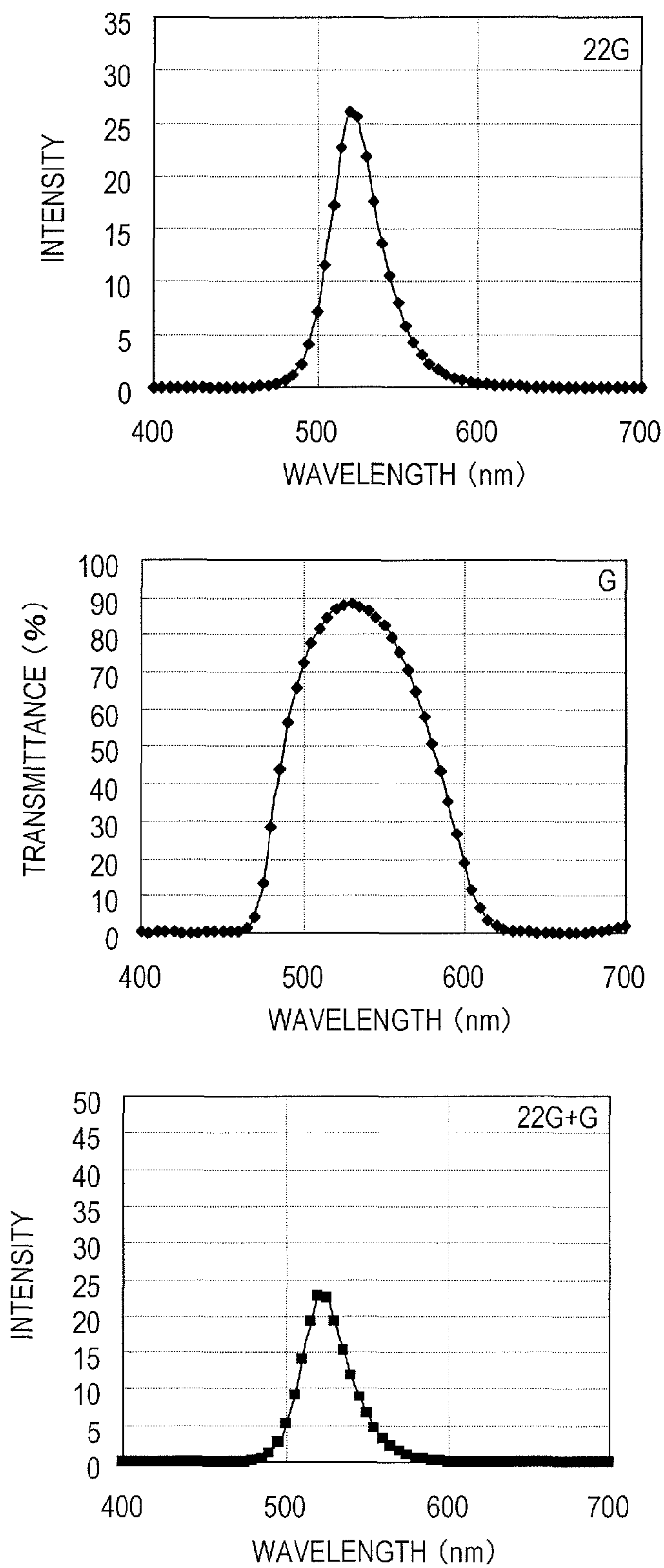


FIG.5

(a)

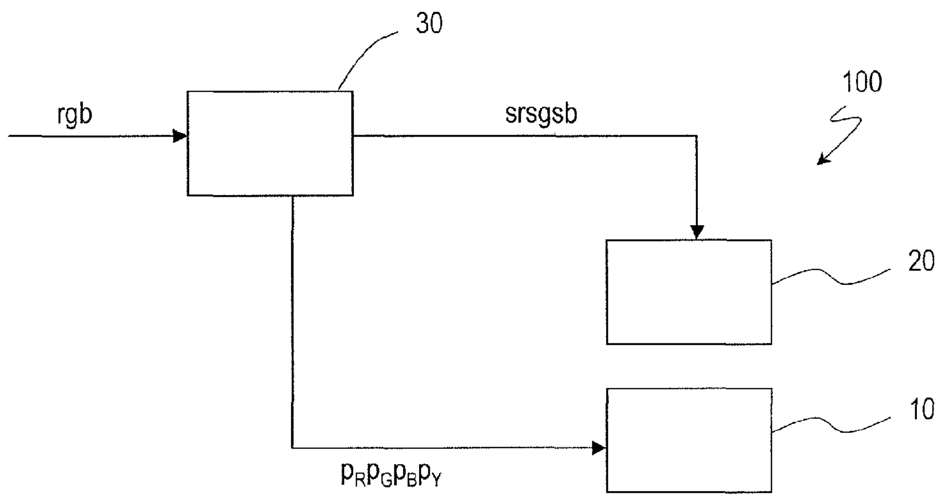
(b)

(c)



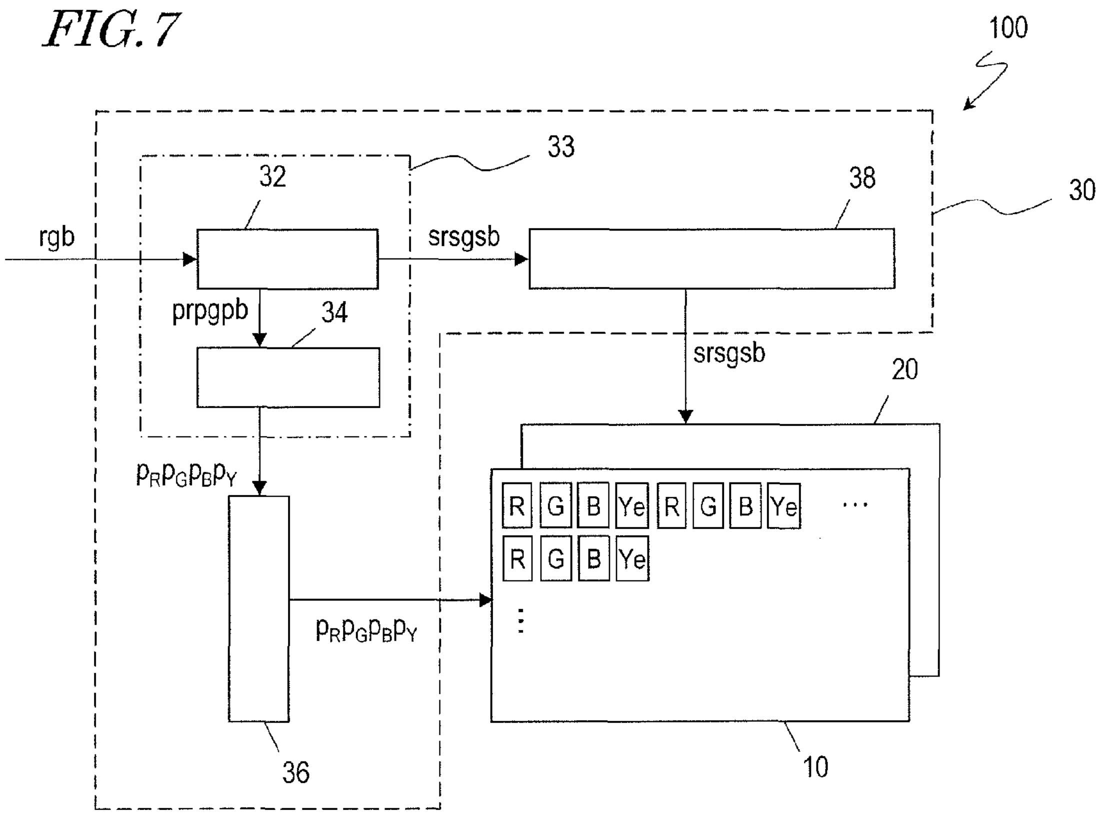
22G
INTENSITY
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)
G
TRANSMITTANCE (%)
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
WAVELENGTH (nm)
22G+G
INTENSITY
50
45
40
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)

FIG. 6



30
100
rgb
srsgsb
20
10
$p_R p_G p_B p_Y$

FIG. 7



100
33
32
38
30
rgb
srsgsb
prpgpb
34
srsgsb
20
$p_R p_G p_B p_Y$
R G B Ye R G B Ye ...
R G B Ye
$p_R p_G p_B p_Y$
36
10

FIG.8

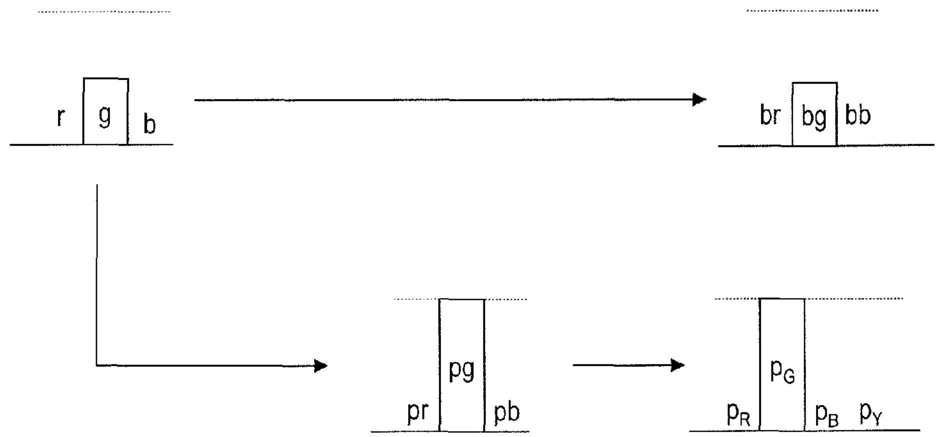


FIG.9

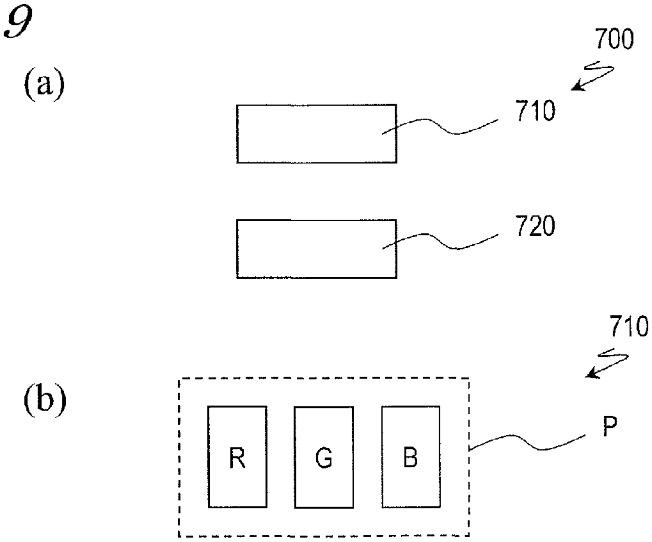


FIG.10

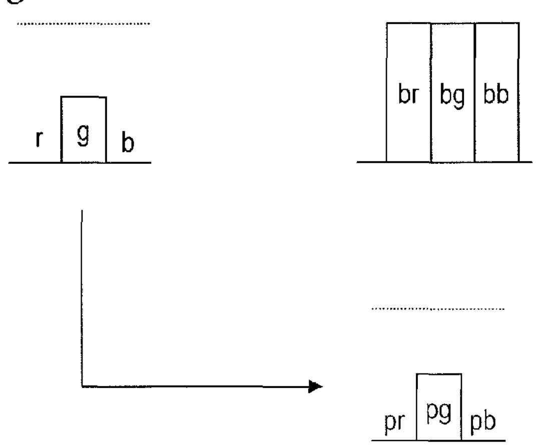


FIG. 11

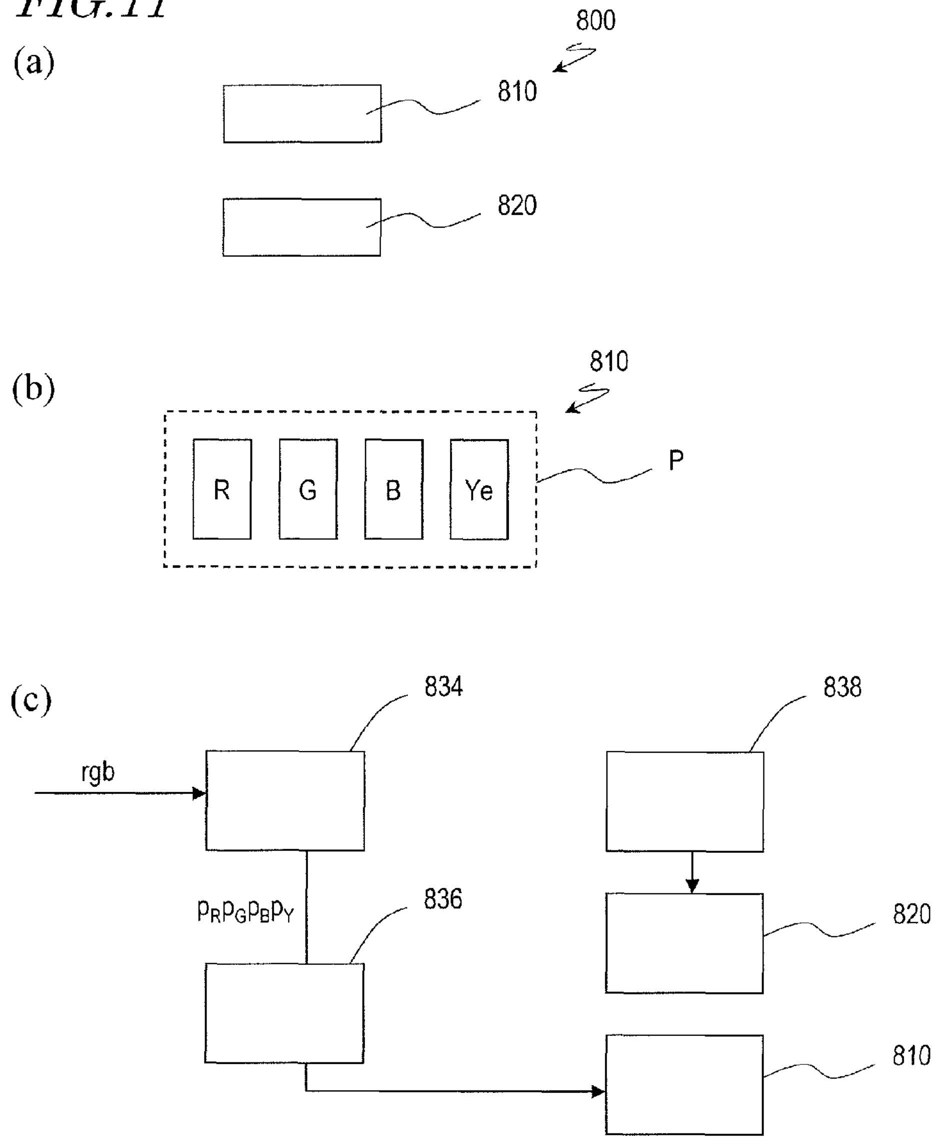

(a)
800
810
820
(b)
810
R
G
B
Ye
P
(c)
834
838
rgb
$p_R p_G p_B p_Y$
836
820
810

FIG. 12

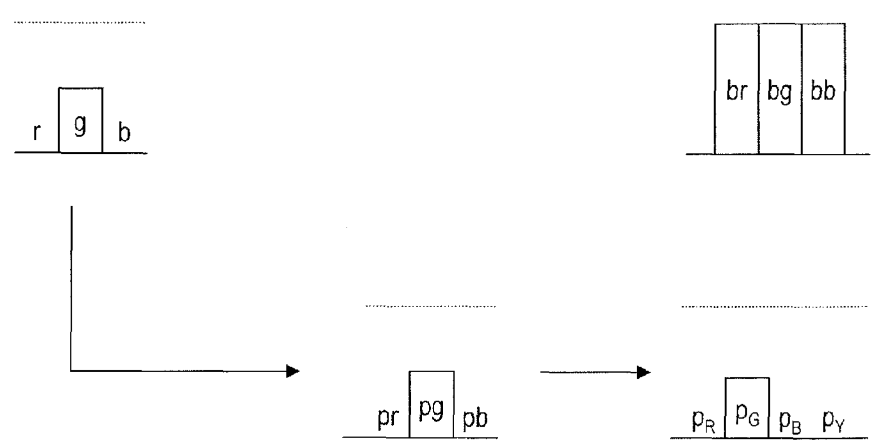

r
g
b
br
bg
bb
pr
pg
pb
p_R
p_G
p_B
p_Y

FIG. 13

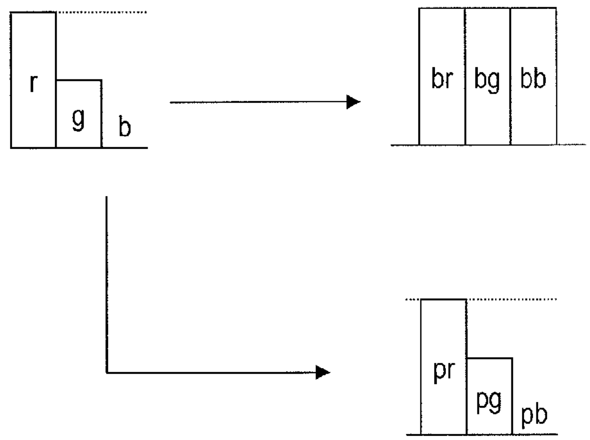


FIG. 14

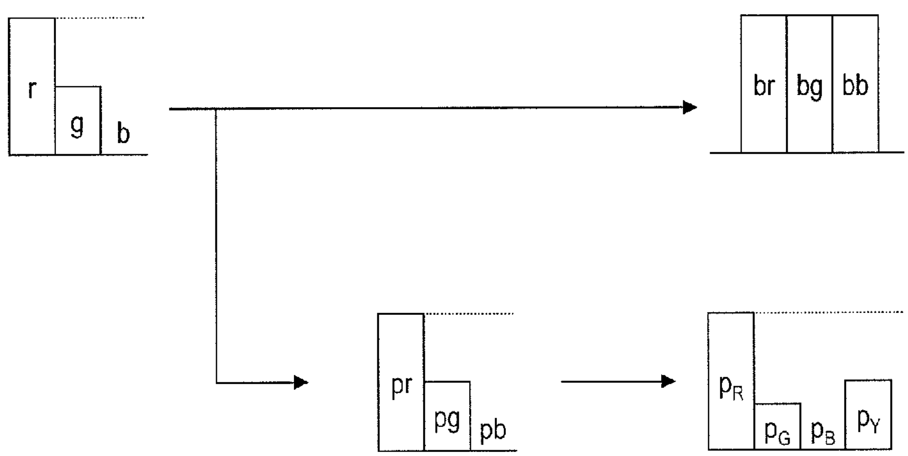


FIG. 15

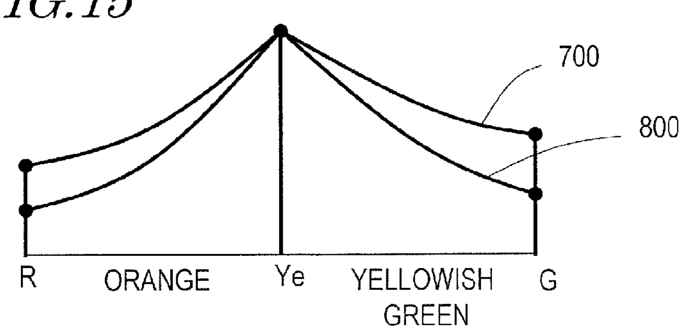


FIG. 16

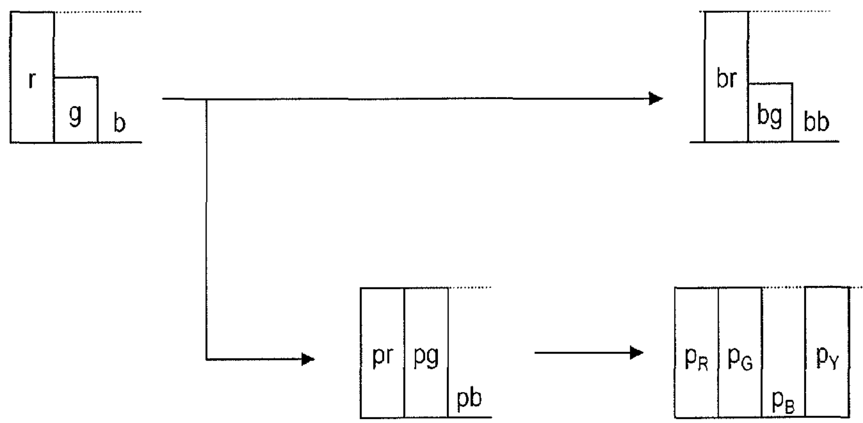


FIG. 17

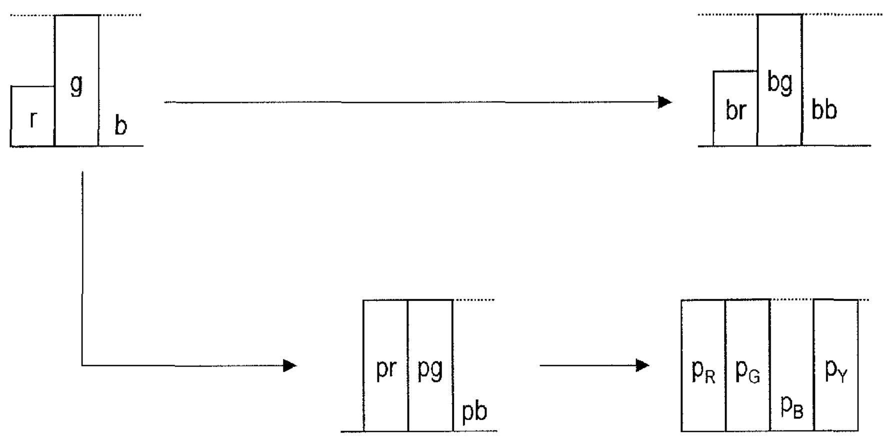


FIG. 18

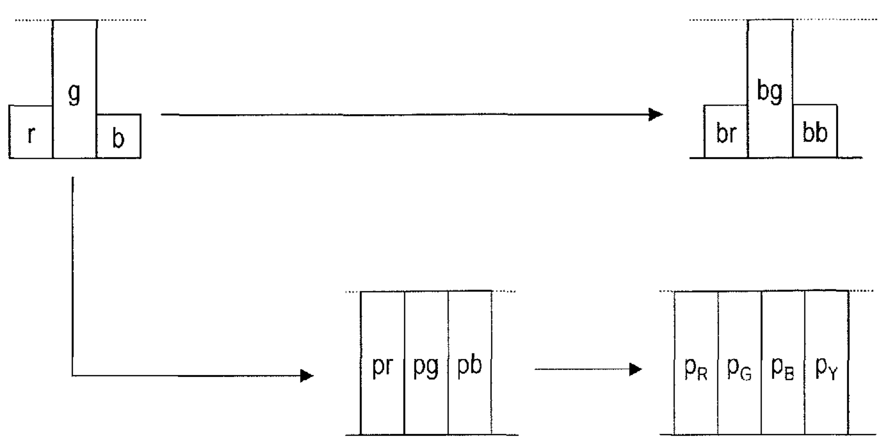


FIG. 19

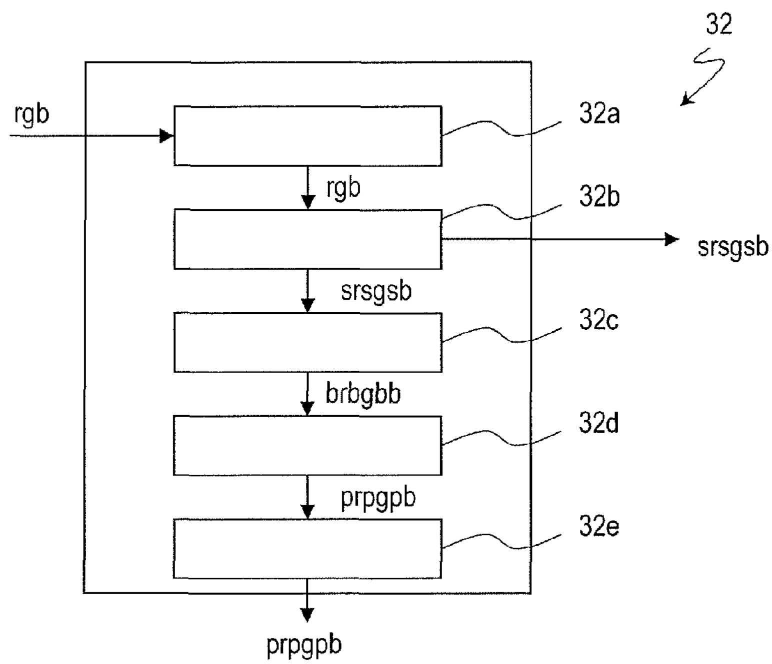

32
rgb
32a
rgb
32b
srsgsb
srsgsb
32c
brbgbb
32d
prpgpb
32e
prpgpb

FIG. 20

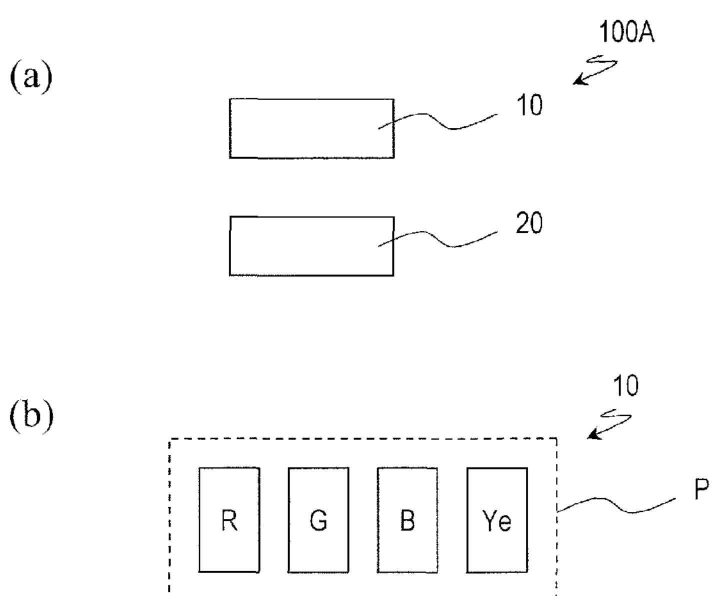

(a)
100A
10
20
(b)
10
R
G
B
Ye
P

FIG.21

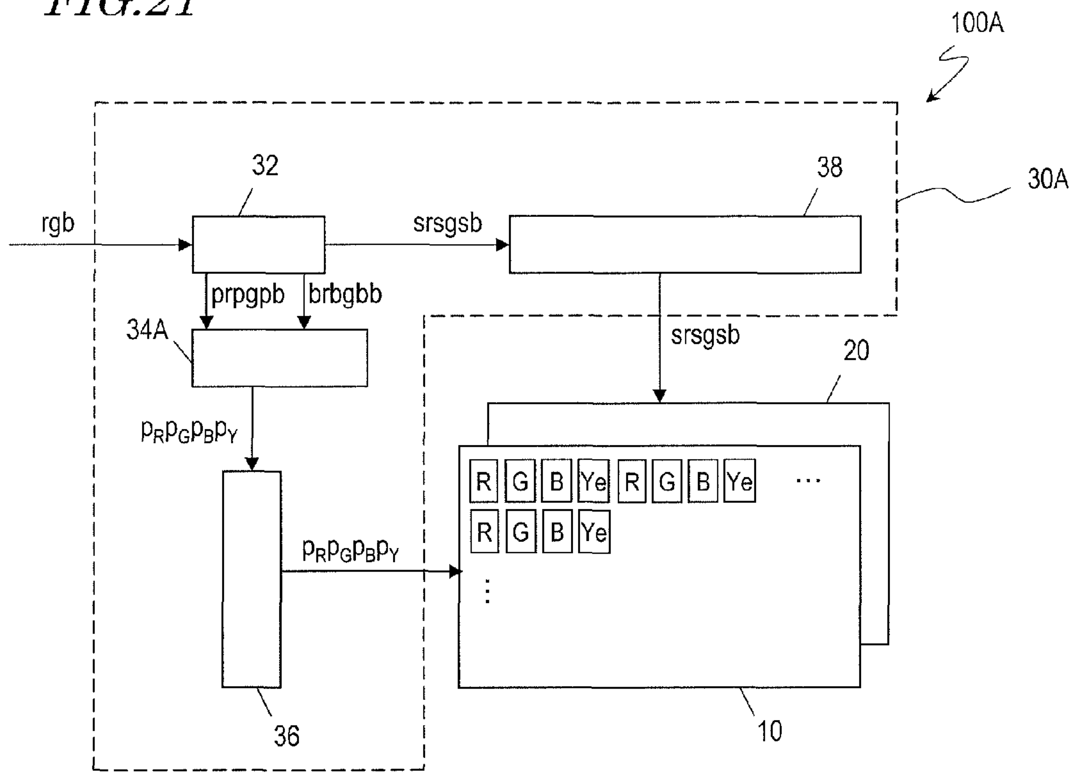

100A
30A
32
38
rgb
srsgsb
prpgpb
brbgbb
34A
srsgsb
20
$p_R p_G p_B p_Y$
R
G
B
Ye
R
G
B
Ye
...
R
G
B
Ye
$p_R p_G p_B p_Y$
36
10

FIG.22

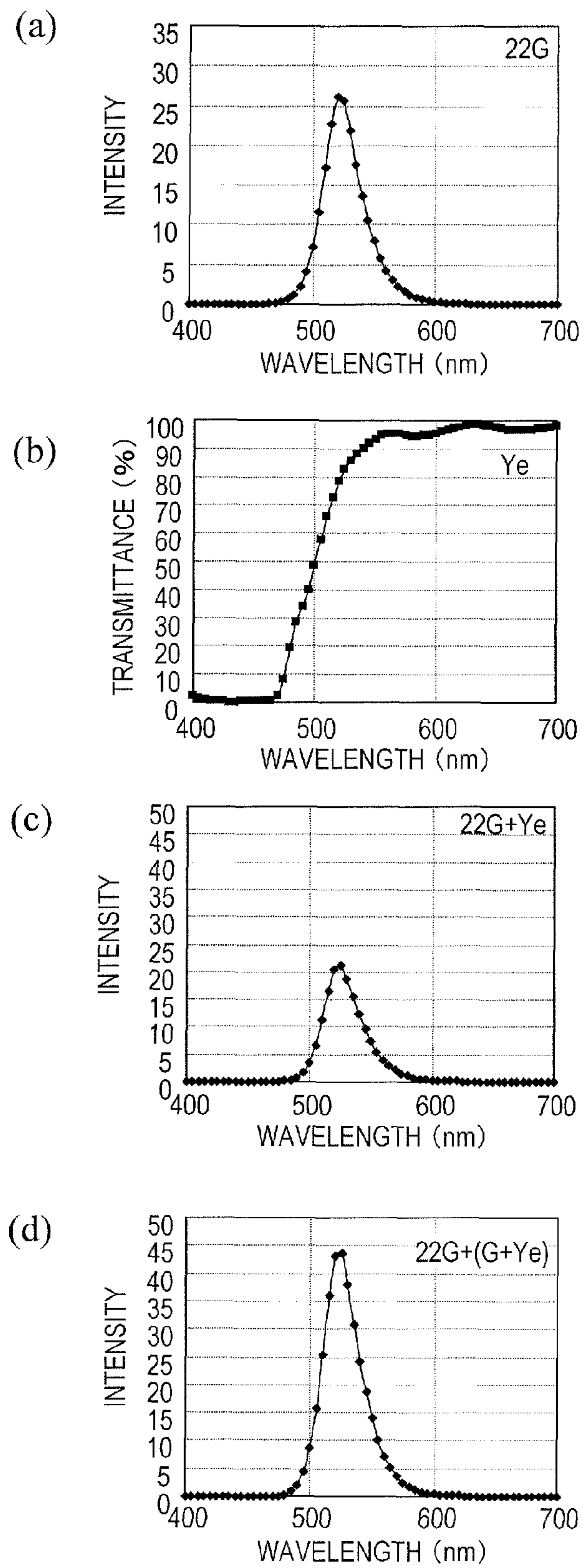

(a)
22G
INTENSITY
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)
(b)
Ye
TRANSMITTANCE (%)
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
WAVELENGTH (nm)
(c)
22G+Ye
INTENSITY
50
45
40
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)
(d)
22G+(G+Ye)
INTENSITY
50
45
40
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)

FIG.23

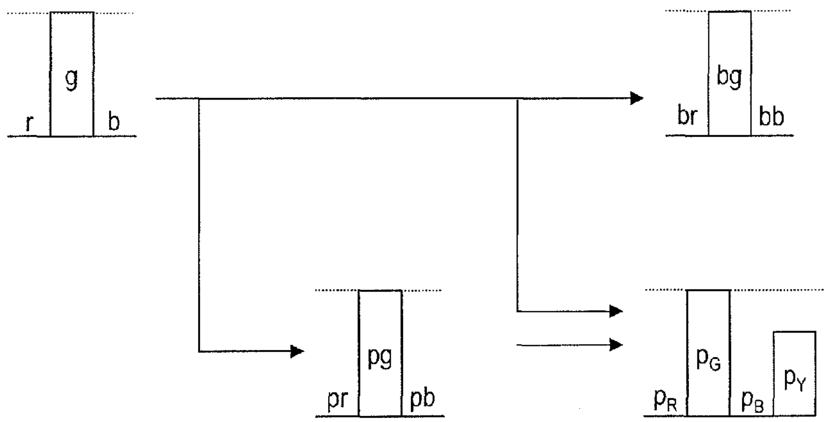


FIG.24

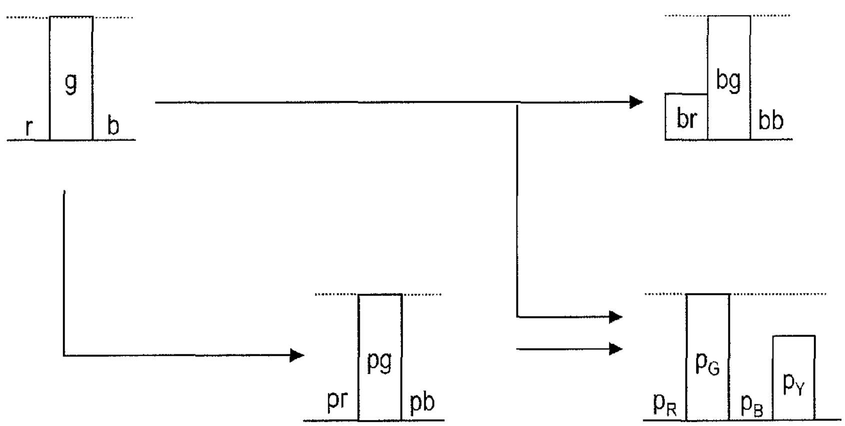


FIG.25

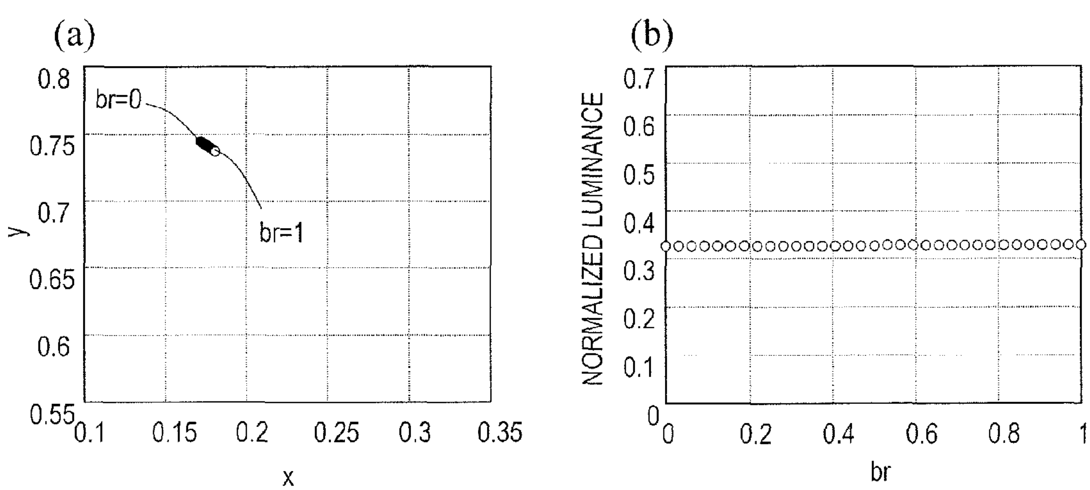


FIG.26

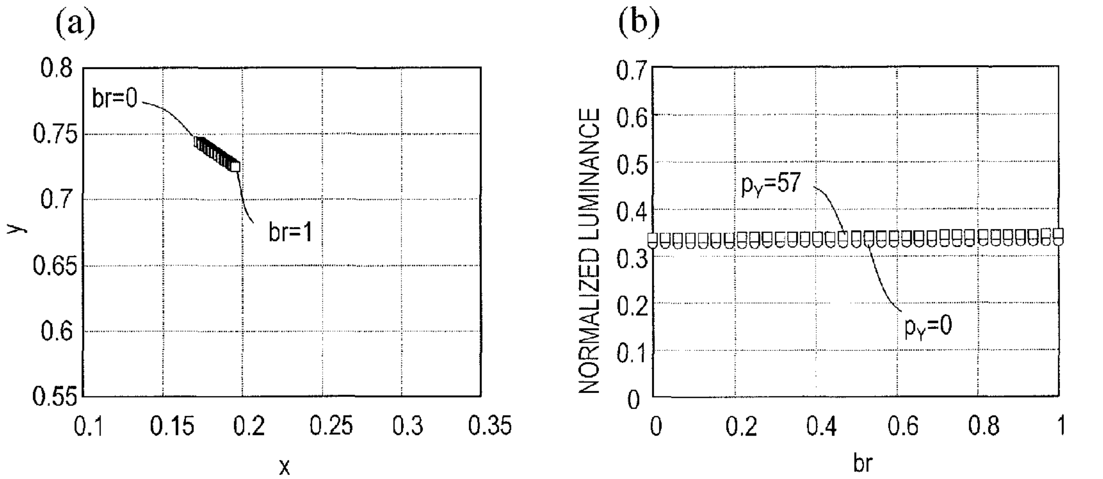


FIG.27

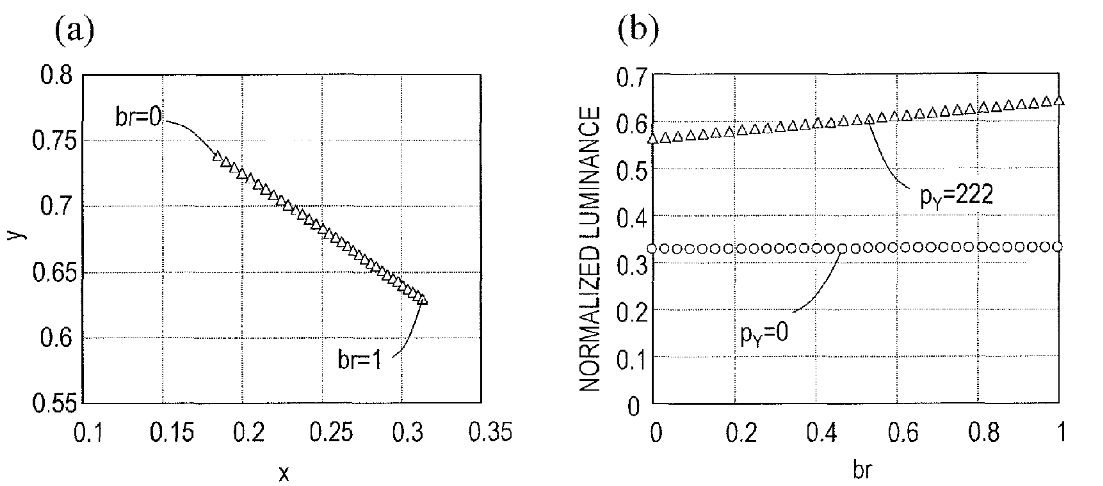


FIG.28

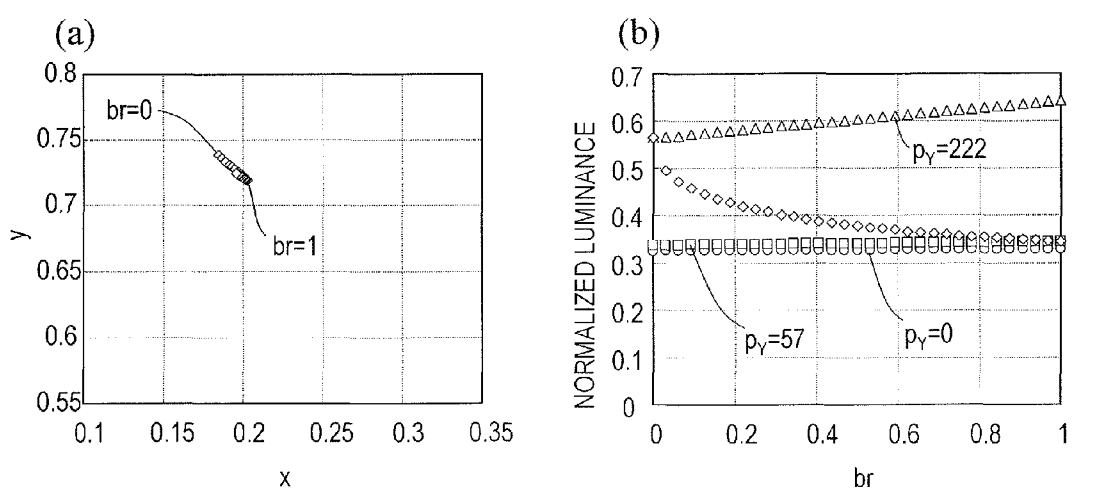


FIG.29

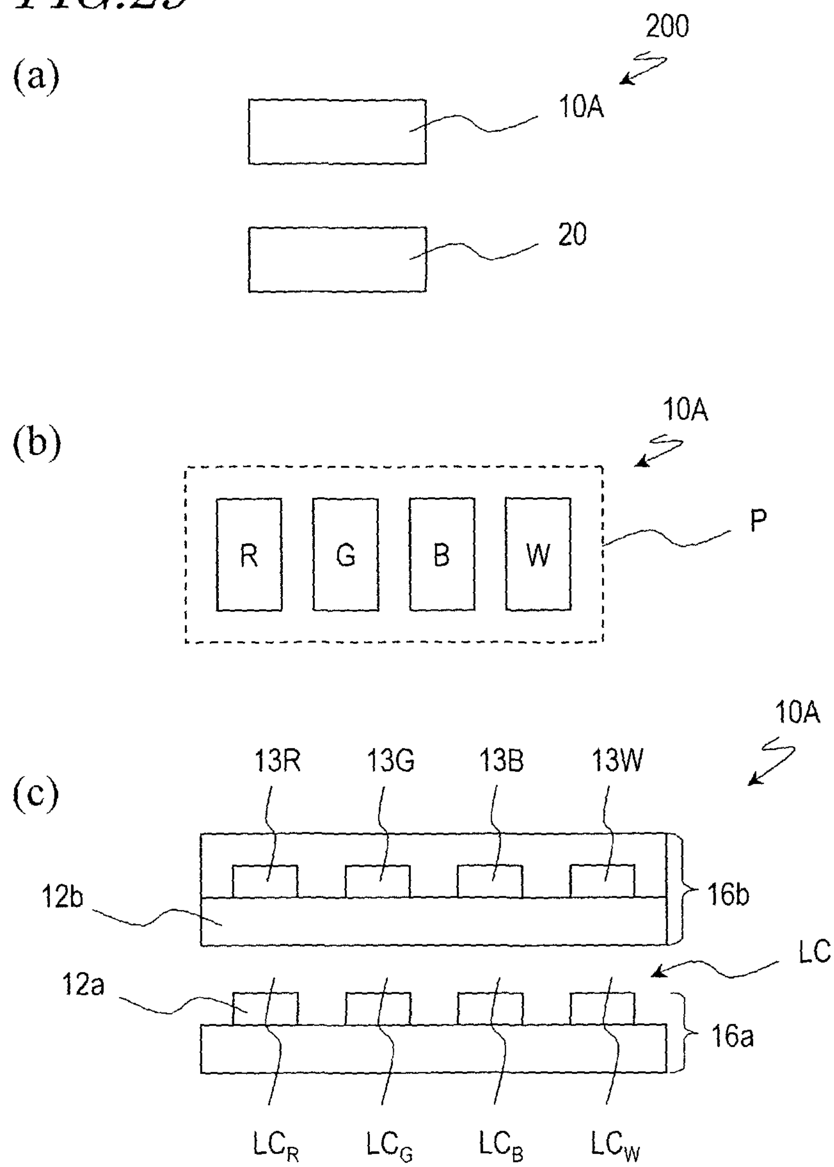

(a)
200
10A
20
(b)
10A
R
G
B
W
P
(c)
10A
13R
13G
13B
13W
12b
16b
LC
12a
16a
LC_R
LC_G
LC_B
LC_W

FIG.30

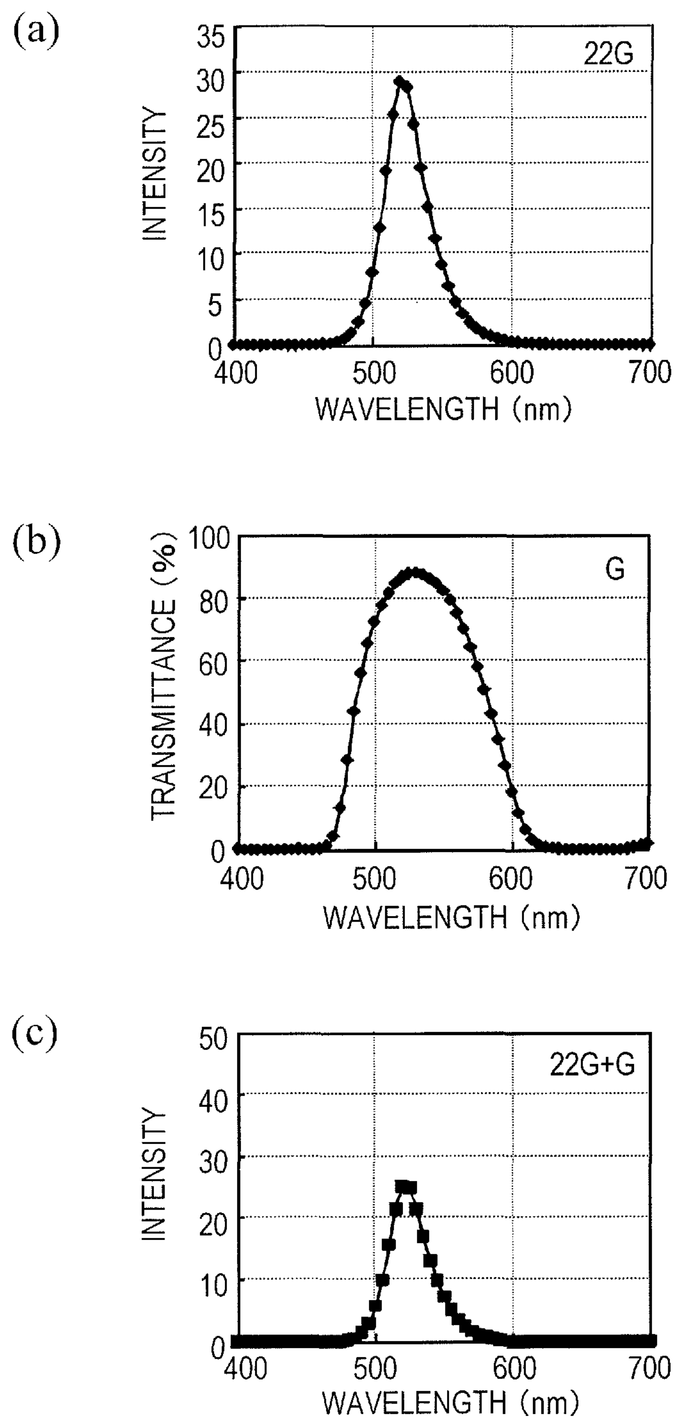
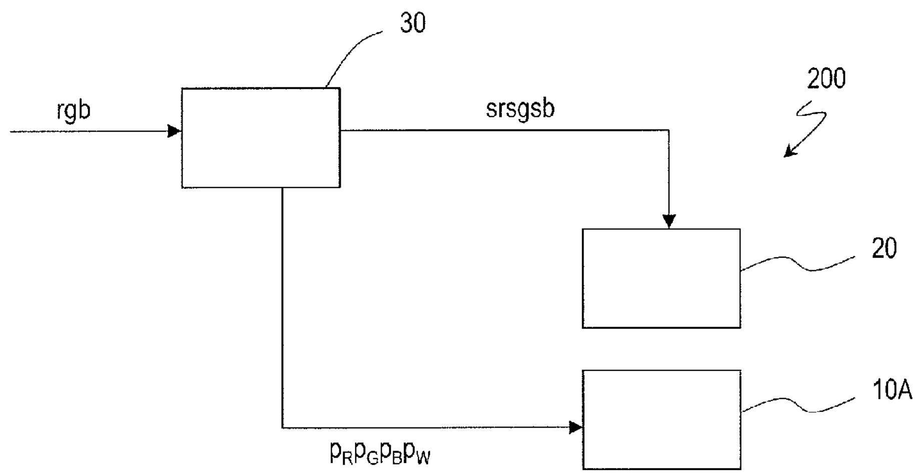
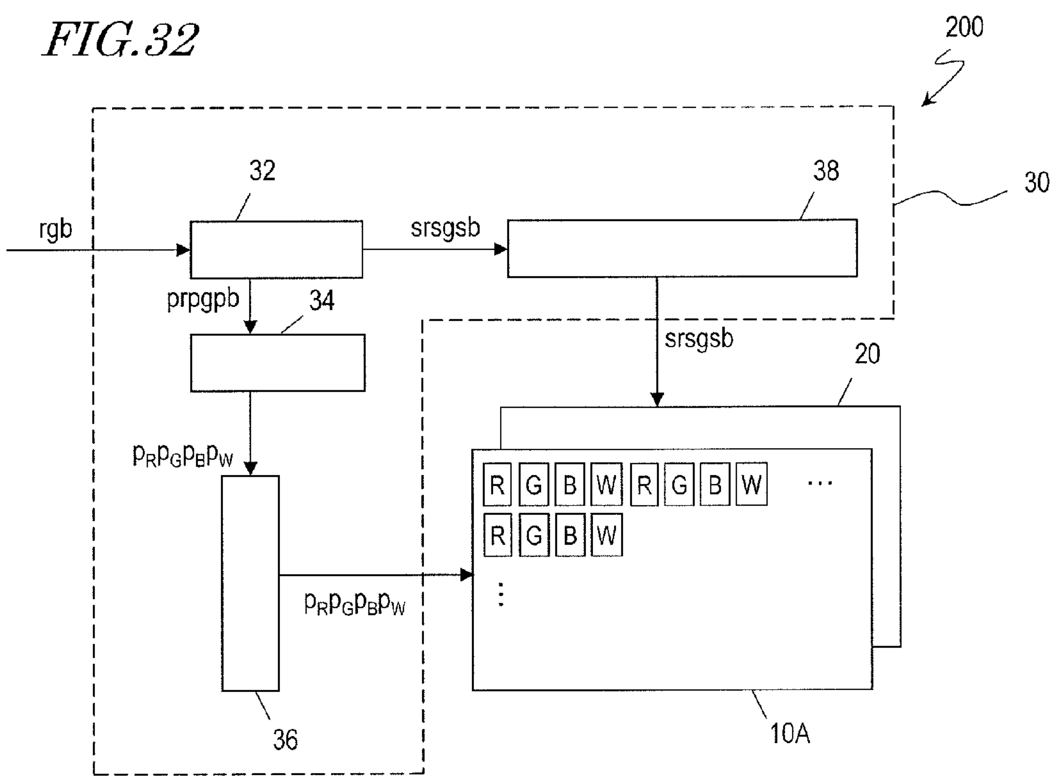

(a)
22G
INTENSITY
35
30
25
20
15
10
5
0
400
500
600
700
WAVELENGTH (nm)
(b)
G
TRANSMITTANCE (%)
100
80
60
40
20
0
400
500
600
700
WAVELENGTH (nm)
(c)
22G+G
INTENSITY
50
40
30
20
10
0
400
500
600
700
WAVELENGTH (nm)

FIG.31



30
rgb
srsgsb
200
20
10A
$p_Rp_Gp_Bp_W$

FIG.32



200
32
38
30
rgb
srsgsb
prpgpb
34
srsgsb
20
$p_Rp_Gp_Bp_W$
R G B W R G B W ...
R G B W
$p_Rp_Gp_Bp_W$
36
10A

FIG.33

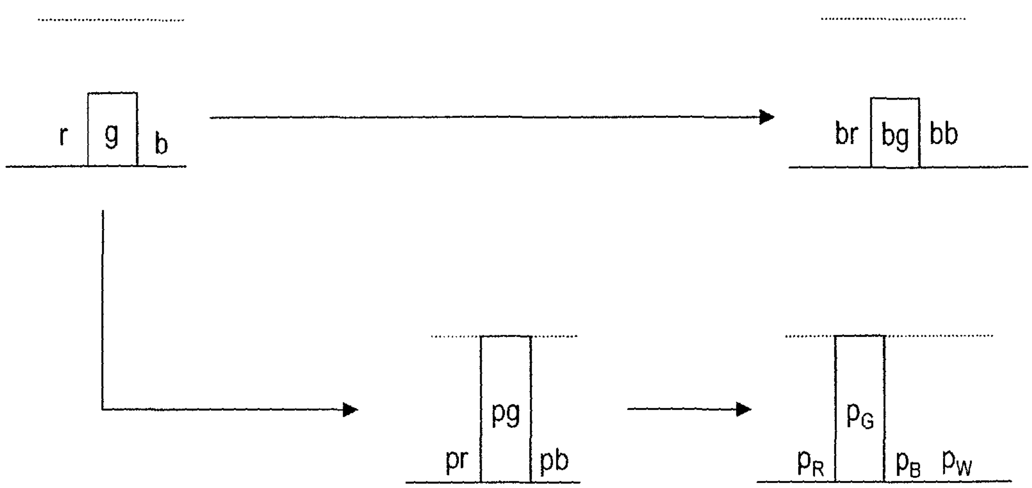


FIG.34

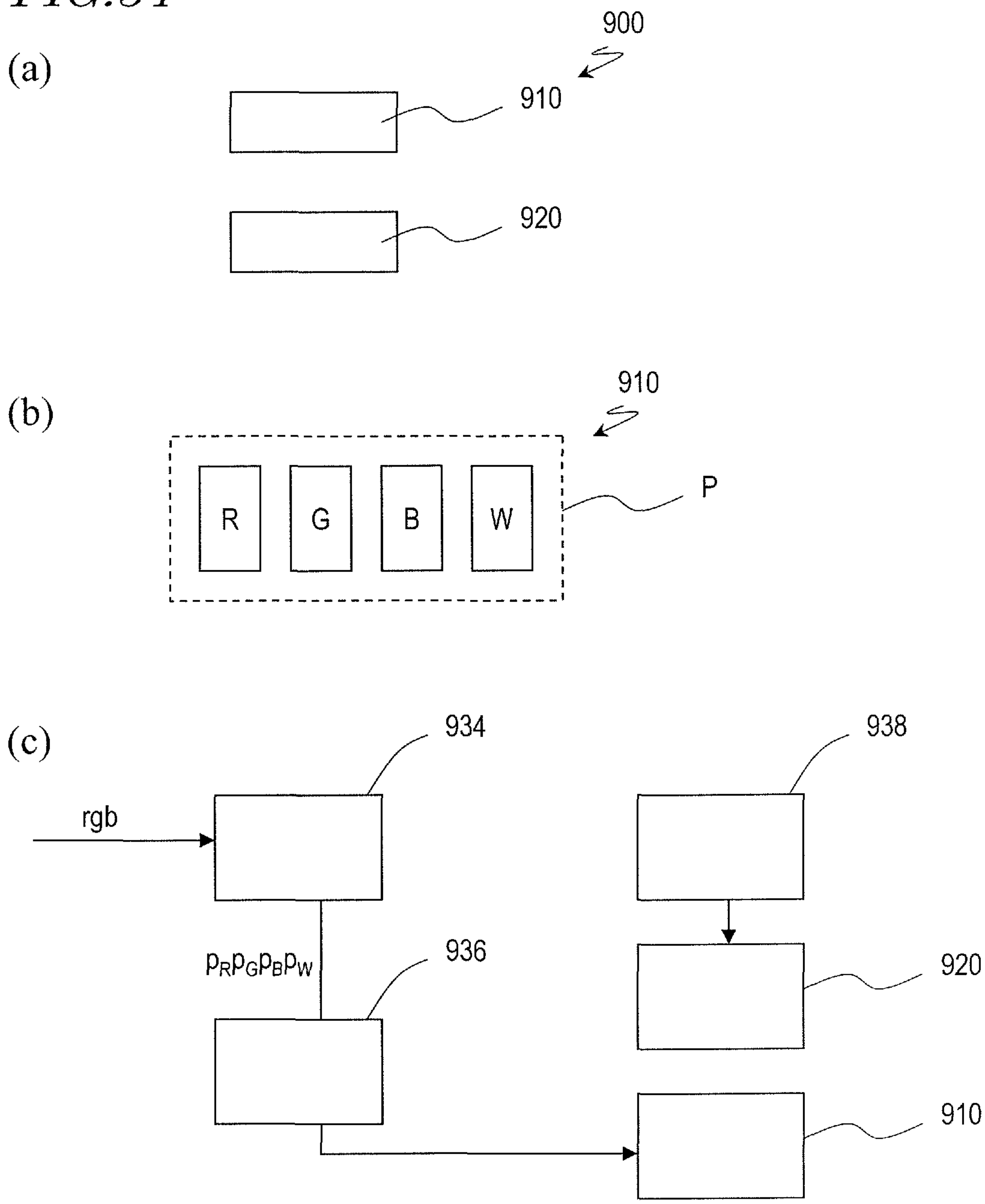


FIG.35

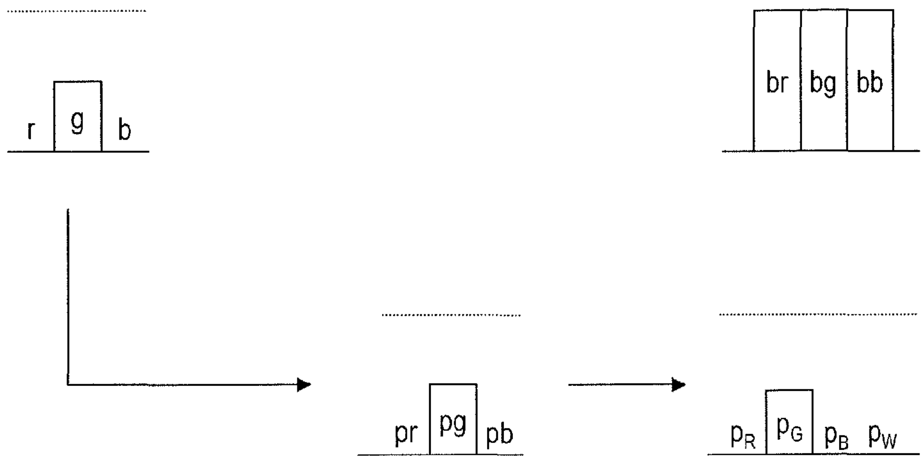


FIG.36

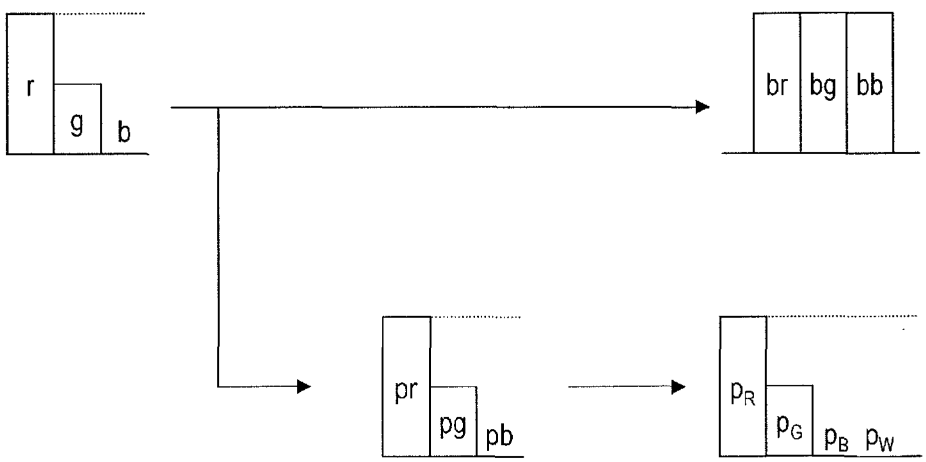


FIG.37

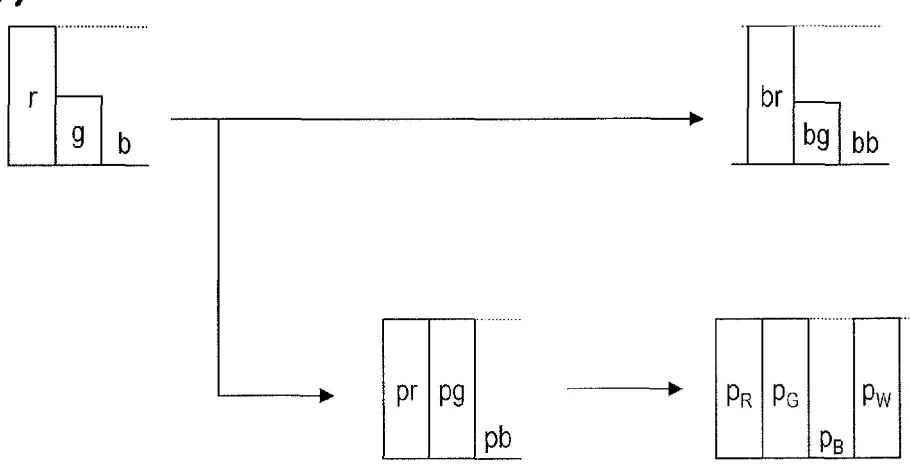


FIG.38

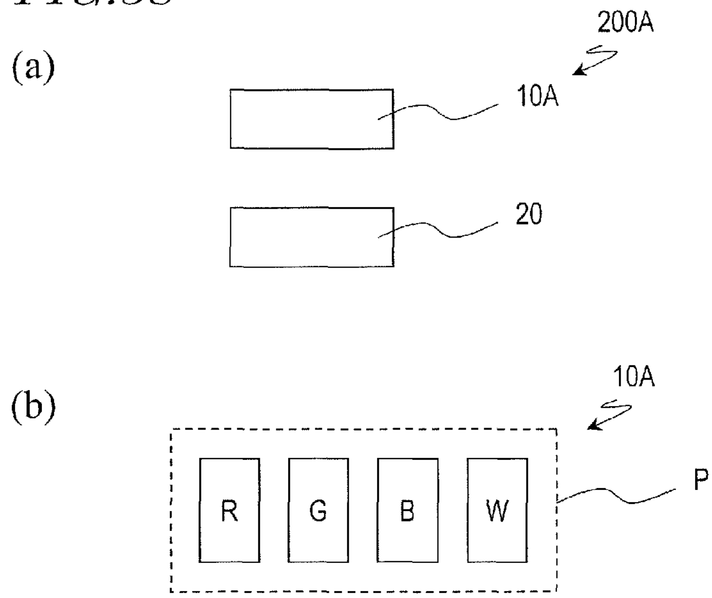

(a)
200A
10A
20
(b)
10A
R
G
B
W
P

FIG.39

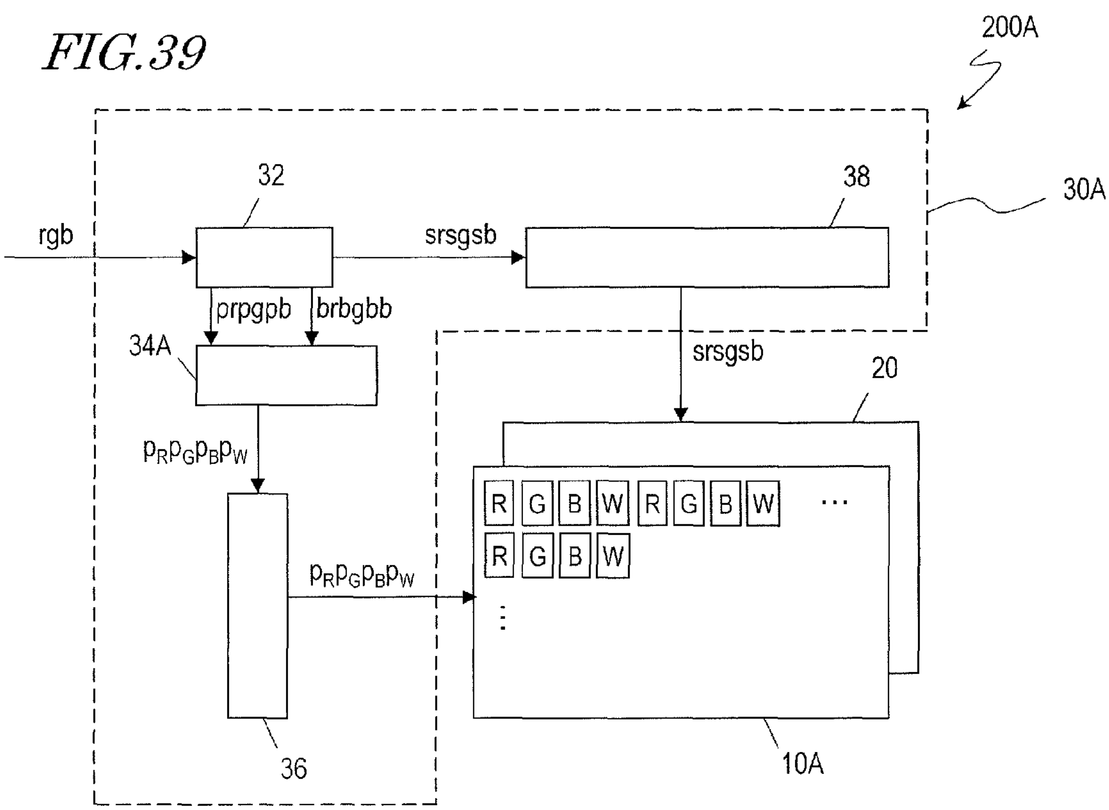

200A
32
38
30A
rgb
srsgsb
prpgpb
brbgbb
34A
srsgsb
20
$p_R p_G p_B p_W$
R G B W R G B W ⋯
R G B W
$p_R p_G p_B p_W$
⋮
36
10A

FIG. 40

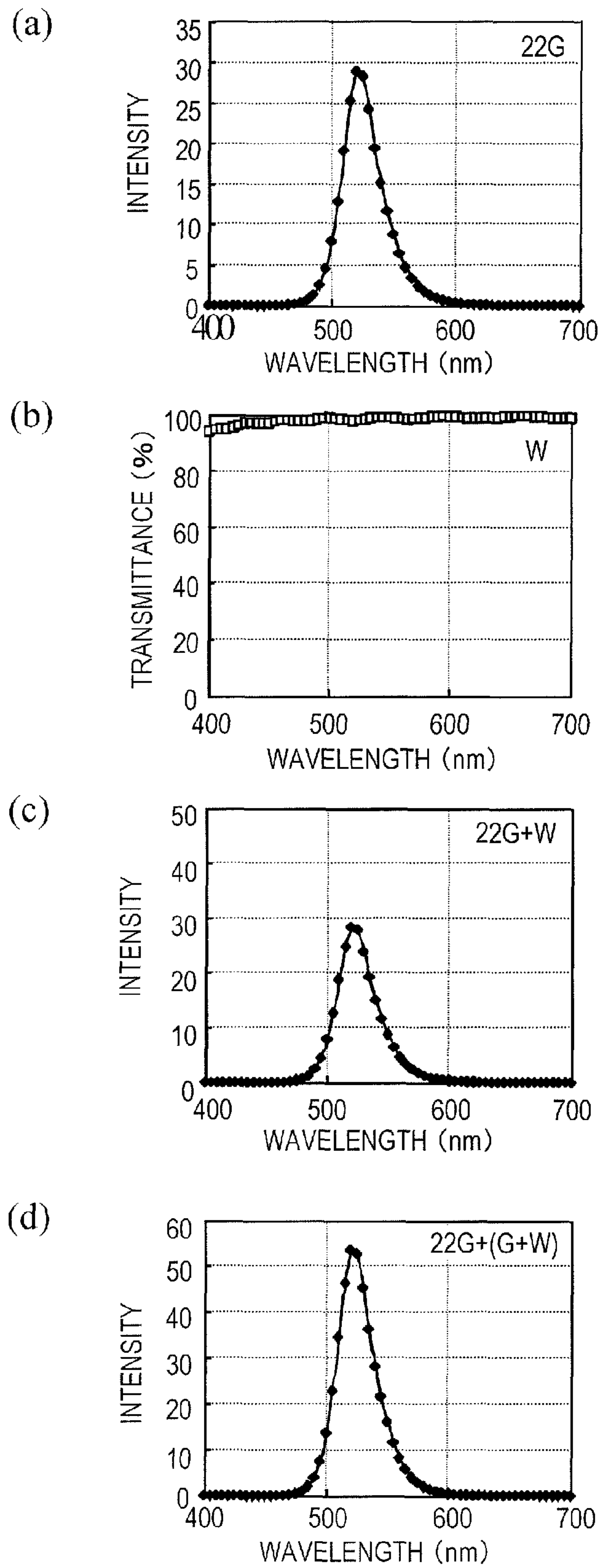

(a)
INTENSITY
WAVELENGTH (nm)
22G
(b)
TRANSMITTANCE (%)
WAVELENGTH (nm)
W
(c)
INTENSITY
WAVELENGTH (nm)
22G+W
(d)
INTENSITY
WAVELENGTH (nm)
22G+(G+W)

FIG. 41

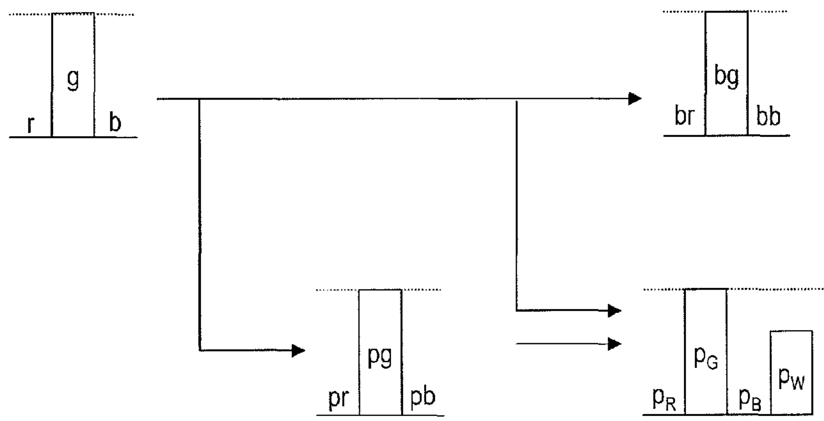


FIG. 42

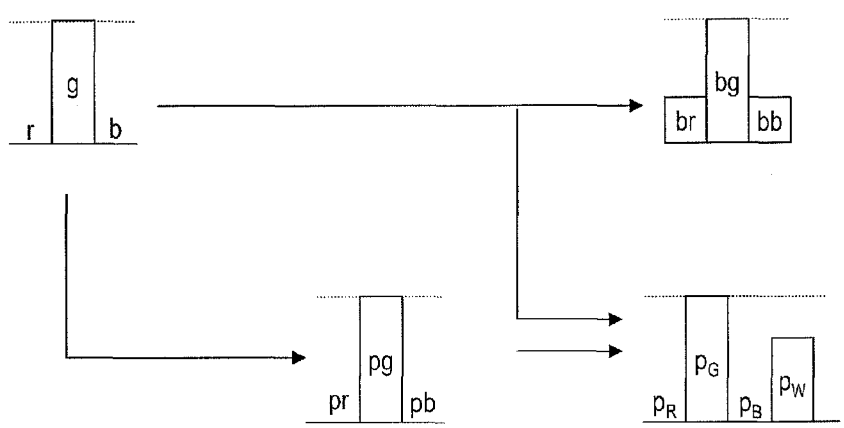


FIG. 43

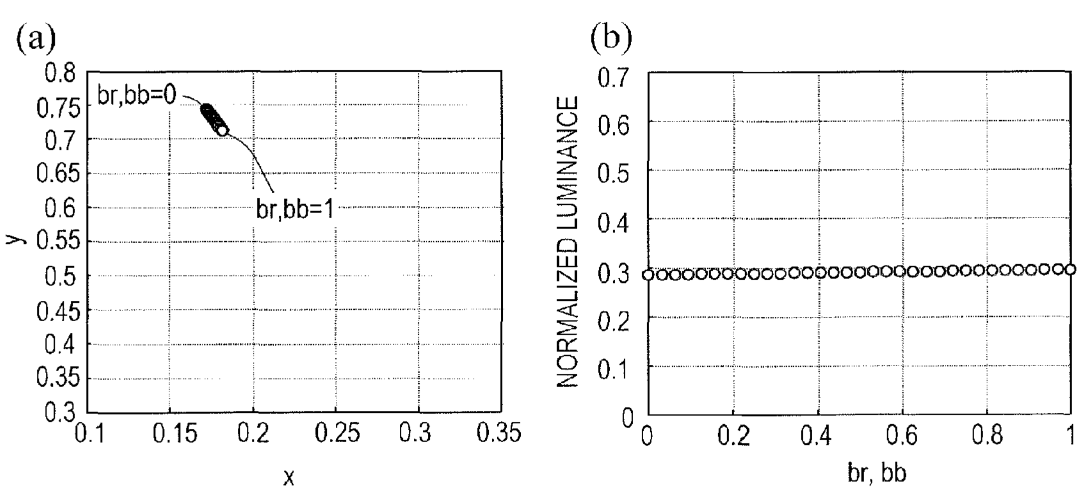


FIG. 44

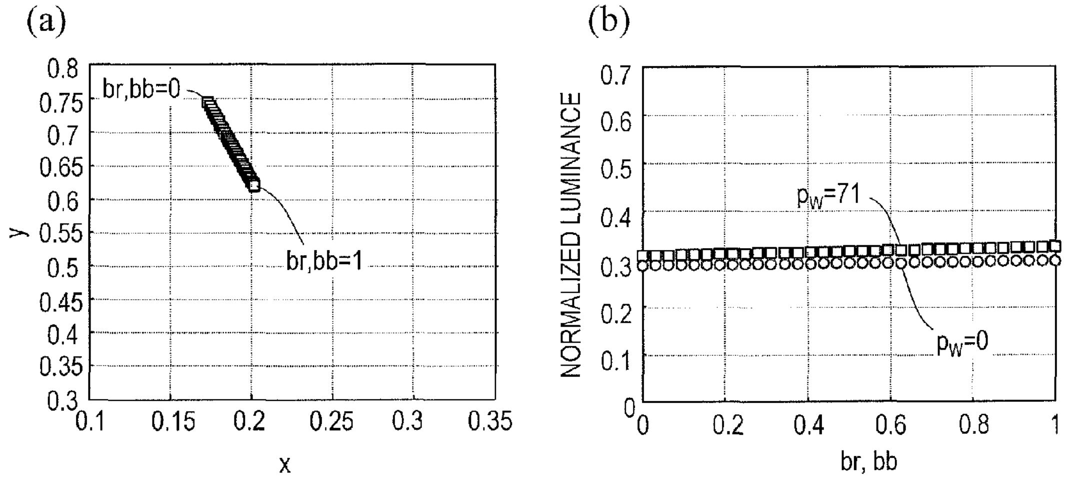


FIG. 45

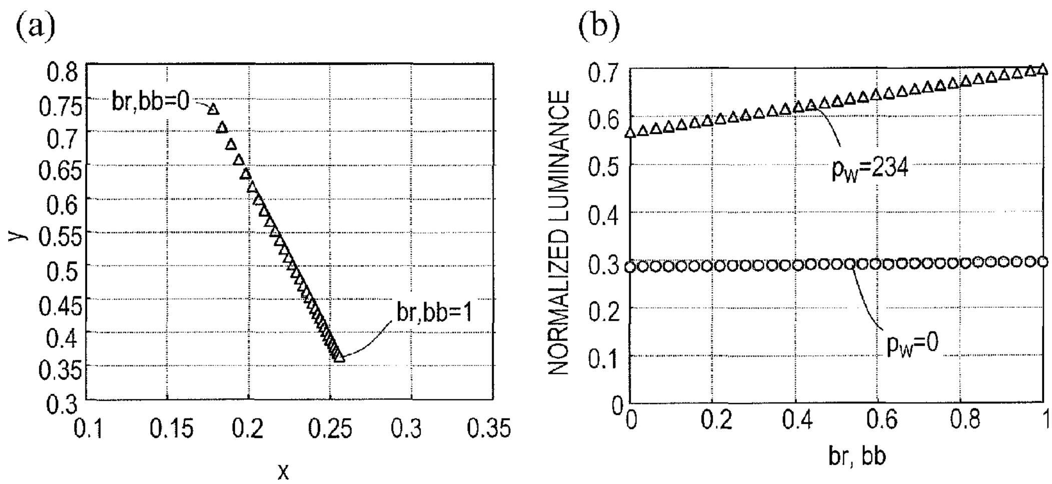
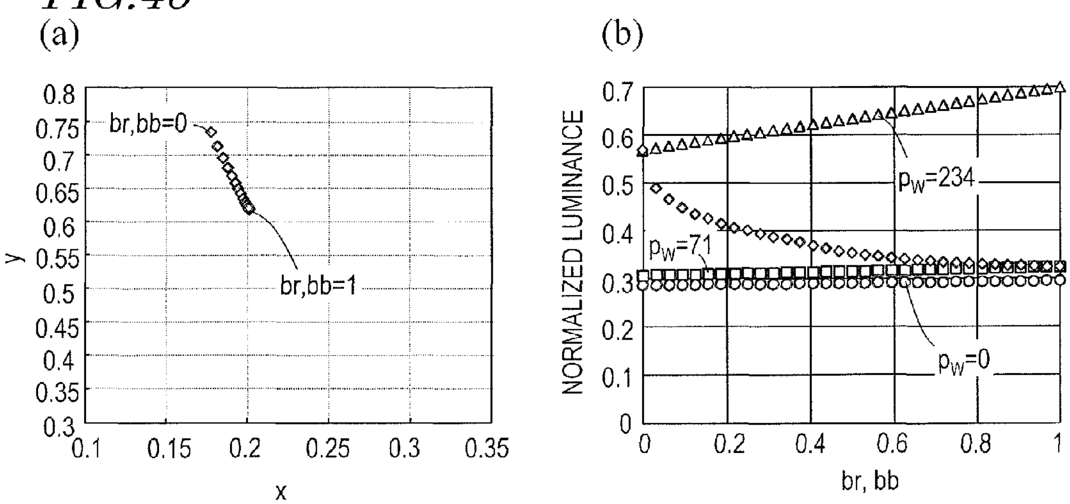


FIG. 46



LIQUID CRYSTAL DISPLAY DEVICE

TECHNICAL FIELD

The present invention relates to a liquid crystal display device, and more particularly to a liquid crystal display device which performs display with four or more primary colors.

BACKGROUND ART

A liquid crystal display device has such advantages as a light and thin body and low power consumption. Because of the advantages, a liquid crystal display device is utilized for not only a small-size display device such as a display portion of a mobile telephone, but also a large-size television set. As for a liquid crystal panel, the liquid crystal panel itself does not emit light, unlike a self-emitting panel such as a cathode ray tube (CRT) and a plasma display panel (PDP). Accordingly, a liquid crystal display device generally performs display by utilizing light of a backlight disposed on a back side of a liquid crystal panel.

In recent years, unlike a general liquid crystal display device with three primary colors, a liquid crystal display device with four or more primary colors which are additively mixed is suggested. Such a liquid crystal display device is also referred to as a multi-primary color liquid crystal display device. In general, in a multi-primary color liquid crystal display device, any other primary color is added to the three primary colors (i.e., red, green, and blue), thereby increasing the color reproduction range. The multi-primary color liquid crystal display device performs display in such a manner that grayscale levels of an input video signal which can be displayed by a general three-primary color display device are converted into grayscale levels of four or more primary colors (see Patent Documents No. 1 and No. 2, for example). Such conversion is also referred to as multi-primary color conversion.

CITATION LIST

Patent Literature

Patent Document No. 1: Japanese Unexamined Patent Application Publication No. 2004-529396

Patent Document No. 2: International Publication No. WO 2007/032133

SUMMARY OF INVENTION

Technical Problem

In a general multi-primary color liquid crystal display device, light of constant intensity is emitted from a backlight in the driving, and a transmittance of a liquid crystal layer is changed by controlling a voltage applied across the liquid crystal layer in a liquid crystal panel, thereby representing various colors. However, in such a liquid crystal display device, the backlight is turned on even in the case where a color of low brightness (e.g. black) is to be displayed. Thus, it is impossible to attempt the reduction of power consumption.

The present invention has been performed in view of the above-described problems, and the objective of the present invention is to provide a liquid crystal display device which performs display of wide color reproduction range with low power consumption.

Solution to Problem

The liquid crystal display device of the present invention is a liquid crystal display device including: a liquid crystal panel

having a plurality of pixels; and a backlight having at least one light source unit that emits light to the liquid crystal panel, wherein each of the plurality of pixels has four or more sub-pixels, and the light source unit includes a red light source, a green light source, and a blue light source.

In one embodiment, the red light source, the green light source, and the blue light source are a red light emitting diode, a green light emitting diode, and a blue light emitting diode, respectively.

In one embodiment, the liquid crystal display device further includes a control circuit that controls the liquid crystal panel and the backlight based on an input video signal.

In one embodiment, the control circuit includes: an active drive processing portion that generates a light source signal and a liquid crystal data signal based on the input video signal; a multi-primary color converting portion that generates a panel signal from the liquid crystal data signal; a panel driving circuit that drives the liquid crystal panel based on the panel signal; and a backlight driving circuit that drives the backlight based on the light source signal.

In one embodiment, the active drive processing portion generates a backlight signal from the light source signal, and the multi-primary color converting portion generates the panel signal based on the backlight signal and the liquid crystal data signal.

In one embodiment, the liquid crystal display device varies relative intensities of the red light source, the green light source, and the blue light source of the light source unit depending on a color of a pixel indicated by the input video signal.

In one embodiment, among the red light source, the green light source, and the blue light source of the light source unit, a light source corresponding to grayscale levels of red, green, and blue having the minimum value of the input video signal is turned off, and a light source corresponding to grayscale levels of red, green, and blue having a value higher than the minimum value of the input video signal is turned on.

In one embodiment, in the case where the input video signal indicates yellow, the red light source and the green light source are turned on, and the blue light source is turned off.

In one embodiment, the magnitude correlation among respective relative intensities of the red light source, the green light source, and the blue light source is the same as the magnitude correlation among red, green, and blue grayscale levels indicated in the input video signal.

In one embodiment, in the case where the red, green, and blue grayscale levels indicated in the input video signal are higher than the minimum value, respectively, respective relative transmittances of the four or more sub-pixels in the liquid crystal panel exhibit the maximum value.

In one embodiment, in the case where the input video signal indicates orange or yellowish green, the blue light source is turned off.

In one embodiment, in the case where the input video signal indicates orange or yellowish green, respective relative intensities of the red light source and the green light source are higher than a relative intensity of the blue light source.

In one embodiment, in the case where the input video signal indicates green, a relative intensity of the green light source is higher than a relative intensity of the red light source and a relative intensity of the blue light source.

In one embodiment, the four or more sub-pixels include a red sub-pixel, a green sub-pixel, a blue sub-pixel, and a yellow sub-pixel.

In one embodiment, in the case where the input video signal indicates yellow, relative transmittances of the red sub-pixel, the green sub-pixel, and the yellow sub-pixel in the liquid crystal panel exhibit the maximum value.

In one embodiment, in the case where the input video signal indicates green, the green light source is turned on, and relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates green, the red light source and the green light source are turned on, and relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the red light source is turned on, a relative transmittance of the red sub-pixel in the liquid crystal panel exhibits the maximum value, in the case where the green light source is turned on, a relative transmittance of the green sub-pixel in the liquid crystal panel exhibits the maximum value, and in the case where the blue light source is turned on, a relative transmittance of the blue sub-pixel in the liquid crystal panel exhibits the maximum value.

In one embodiment, in the case where the red light source is turned on and the green light source is turned off, relative transmittances of the red sub-pixel and the yellow sub-pixel are higher than the minimum value, and in the case where the green light source is turned on and the red light source is turned off, relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than the minimum value.

In one embodiment, the four or more sub-pixels further include a cyan sub-pixel.

In one embodiment, the four or more sub-pixels include a red sub-pixel, a green sub-pixel, a blue sub-pixel, and a white sub-pixel.

In one embodiment, in the case where the input video signal indicates green, the green light source is turned on, and relative transmittances of the green sub-pixel and the white sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates red, the red light source is turned on, and relative transmittances of the red sub-pixel and the white sub-pixel are higher than relative transmittances of the green sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates blue, the blue light source is turned on, and relative transmittances of the blue sub-pixel and the white sub-pixel are higher than relative transmittances of the red sub-pixel and the green sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates green, the green light source is turned on, the red light source and/or the blue light source are turned on, and relative transmittances of the green sub-pixel and the white sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates red, the red light source is turned on, the green light source and/or the blue light source are turned on, and relative transmittances of the red sub-pixel and the white sub-pixel are higher than relative transmittances of the green sub-pixel and the blue sub-pixel in the liquid crystal panel.

In one embodiment, in the case where the input video signal indicates blue, the blue light source is turned on, the red light source and/or the green light source are turned on, and relative transmittances of the blue sub-pixel and the white sub-pixel are higher than relative transmittances of the red sub-pixel and the green sub-pixel.

In one embodiment, in the case where the red light source is turned on, a relative transmittance of the red sub-pixel in the liquid crystal panel exhibits the maximum value, in the case where the green light source is turned on, a relative transmittance of the green sub-pixel in the liquid crystal panel exhibits the maximum value, and in the case where the blue light source is turned on, a relative transmittance of the blue sub-pixel in the liquid crystal panel exhibits the maximum value.

In one embodiment, in the case where the red light source is turned on, and the green light source and the blue light source are turned off, relative transmittances of the red sub-pixel and the white sub-pixel are higher than the minimum value, in the case where the green light source is turned on, and the red light source and the blue light source are turned off, relative transmittances of the green sub-pixel and the white sub-pixel are higher than the minimum value, and in the case where the blue light source is turned on, and the red light source and the green light source are turned off, relative transmittances of the blue sub-pixel and the white sub-pixel are higher than the minimum value.

Advantageous Effects of Invention

The liquid crystal display device of the present invention can perform display of wide color reproduction range with low power consumption.

BRIEF DESCRIPTION OF DRAWINGS

In FIG. **1**, (a) is a schematic diagram of a liquid crystal display device in a first embodiment of the present invention, (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a), (c) is a schematic sectional view of the liquid crystal panel shown in (b), (d) is a schematic diagram of a backlight in the liquid crystal display device shown in (a), and (e) is a schematic diagram of a light source unit shown in (d).

FIG. **2** is a graph showing transmission spectra of red, green, blue and yellow sub-pixels in the liquid crystal panel shown in FIG. **1**(*b*).

FIG. **3** is a graph showing emission spectra of a red light source, a green light source, and a blue light source shown in FIG. **1**(*e*).

FIG. **4** is a schematic diagram of the liquid crystal display device shown in FIG. **1**.

FIG. **5** shows graphs of the liquid crystal display device shown in FIG. **1** in the case where an input video signal indicates green, in which (a) is a graph showing an emission spectrum of the backlight, (b) is a graph showing a transmission spectrum of the liquid crystal panel, and (c) is a graph showing an emitted light spectrum in the case of (b).

FIG. **6** is a schematic diagram showing an example of the liquid crystal display device shown in FIG. **1**.

FIG. **7** is a schematic diagram of the liquid crystal display device shown in FIG. **6**.

FIG. **8** is a schematic diagram showing luminance levels of an input video signal, relative intensities of a backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of a liquid crystal panel in the liquid crystal display device shown in FIG. **7**.

In FIG. **9**, (a) is a schematic diagram of a liquid crystal display device in a comparative example 1, and (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a).

FIG. **10** is a schematic diagram showing luminance levels of an input video signal, relative intensities of a backlight, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 1.

In FIG. **11**, (a) is a schematic diagram of a liquid crystal display device in a comparative example 2, (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a), and (c) is a schematic diagram of the liquid crystal display device shown in (a).

FIG. **12** is a schematic diagram showing luminance levels of an input video signal, relative intensities of a backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 2.

FIG. **13** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 1.

FIG. **14** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 2.

FIG. **15** is a graph showing normalized luminance of the liquid crystal display devices in the comparative examples 1 and 2 in the case where the color phase of color indicated in an input video signal is varied in the range from red to green via yellow.

FIG. **16** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **1**.

FIG. **17** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **1**.

FIG. **18** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **1**.

FIG. **19** is a schematic diagram showing the configuration of an active drive processing portion shown in FIG. **7**.

In FIG. **20**, (a) is a schematic diagram of a liquid crystal display device in a second embodiment of the present invention, and (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a).

FIG. **21** is a schematic diagram showing an example of the liquid crystal display device shown in FIG. **20**.

FIG. **22** shows graphs of the liquid crystal display device shown in FIG. **20** in the case where an input video signal indicates green, in which (a) is a graph showing an emission spectrum of a backlight, (b) is a graph showing a transmission spectrum of a yellow sub-pixel in the liquid crystal panel, (c) is a graph showing an emitted light spectrum in the case of (a) and (b), and (d) is a graph showing an emitted light spectrum of the liquid crystal display device shown in FIG. **20**.

FIG. **23** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **20**.

FIG. **24** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **20**.

FIG. **25** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **20**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **26** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **20**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **27** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **20**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **28** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **20**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

In FIG. **29**, (a) is a schematic diagram of a liquid crystal display device in a third embodiment of the present invention, (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a), and (c) is a schematic sectional view of the liquid crystal panel shown in (b).

FIG. **30** shows graphs of the liquid crystal display device shown in FIG. **29** in the case where an input video signal indicates green, in which (a) is a graph showing an emission spectrum of a backlight, (b) is a graph showing a transmission spectrum of the liquid crystal panel, and (c) is a graph showing an emitted light spectrum in the case of (a) and (b).

FIG. **31** is a schematic diagram showing an example of the liquid crystal display device shown in FIG. **29**.

FIG. **32** is a schematic diagram of the liquid crystal display device shown in FIG. **31**.

FIG. **33** is a schematic diagram showing luminance levels of an input video signal, relative intensities of the backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **32**.

In FIG. **34**, (a) is a schematic diagram of a liquid crystal display device in a comparative example 3, (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a), and (c) is a schematic diagram of the liquid crystal display device shown in (a).

FIG. **35** is a schematic diagram showing luminance levels of an input video signal, relative intensities of a backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 3.

FIG. **36** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device in the comparative example 3.

FIG. **37** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **29**.

In FIG. **38**, (a) is a schematic diagram of a liquid crystal display device in a fourth embodiment of the present invention, and (b) is a schematic diagram of a liquid crystal panel in the liquid crystal display device shown in (a).

FIG. **39** is a schematic diagram showing an example of the liquid crystal display device shown in FIG. **38**.

FIG. **40** shows graphs of the liquid crystal display device shown in FIG. **38** in the case where an input video signal indicates green, in which (a) is a graph showing an emission spectrum of backlight, (b) is a graph showing a transmission spectrum of a yellow sub-pixel in the liquid crystal panel, (c) is a graph showing an emitted light spectrum in the case of (a) and (b), and (d) is a graph showing an emitted light spectrum of the liquid crystal display device shown in FIG. **38**.

FIG. **41** is a schematic diagram showing luminance levels of an input video signal, relative intensities of the backlight, transmittance levels of a liquid crystal data signal, and relative transmittances of the liquid crystal panel in the liquid crystal display device shown in FIG. **38**.

FIG. **42** is a schematic diagram showing luminance levels of the input video signal, relative intensities of the backlight, transmittance levels of the liquid crystal data signal, and relative transmittances of the a liquid crystal panel in the liquid crystal display device shown in FIG. **38**.

FIG. **43** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **38**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **44** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **38**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **45** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **38**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

FIG. **46** shows graphs showing the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity of the red light source in the backlight in the case where the input video signal indicates green in the liquid crystal display device shown in FIG. **38**, in which (a) is a graph showing the variation of chromaticity, and (b) is a graph showing the variation of normalized luminance.

DESCRIPTION OF EMBODIMENTS

Hereinafter with reference to the accompanying drawings, embodiments of a liquid crystal display device of the present invention will be described. It is noted that the present invention should not be limited to the embodiments which will be described below.

(Embodiment 1)

Hereinafter a first embodiment of the liquid crystal display device of the present invention will be described. FIG. **1**(*a*) shows a schematic diagram of a liquid crystal display device **100** in this embodiment. The liquid crystal display device **100** includes a liquid crystal panel **10** and a backlight **20**.

The liquid crystal panel **10** has a plurality of pixels. The plurality of pixels are arranged in a matrix of a plurality of rows and a plurality of columns. Each pixel is defined by four or more sub-pixels. The liquid crystal panel **10** and the liquid crystal display device **100** are also referred to as a multi-primary color panel and a multi-primary color display device, respectively.

FIG. **1**(*b*) shows a schematic diagram of a pixel P in the liquid crystal panel **10**. The pixel P includes four or more sub-pixels. The four or more sub-pixels display colors which are different from each other. The pixel P is also referred to as a color display pixel. Herein the pixel P includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a yellow sub-pixel Ye.

In FIG. **1**(*b*), the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are shown in a line along a row direction. Alternatively, the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye may be arranged in a matrix of two rows and two columns. In FIG. **1**(*b*), areas of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are shown so as to be equal to each other. Alternatively, the areas of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye may be different. When an average of the areas of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye is referred to as a sub-pixel average area, the area of the red sub-pixel R is larger than the sub-pixel average area, so that the red color of high brightness can sufficiently be represented. The area of the blue sub-pixel B is larger than the sub-pixel average area, so that it is possible to suppress the reduction of luminous efficiency of the backlight. For the above-described reasons, it is preferred that the areas of the red sub-pixel R and the blue sub-pixel B be larger than the area of the green sub-pixel G and the yellow sub-pixel Ye.

FIG. **1**(*c*) shows a schematic sectional view of the liquid crystal panel **10**. In the liquid crystal panel **10**, each of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye includes a pair of electrodes **12***a* and **12***b* and a liquid crystal layer LC positioned between the electrodes **12***a* and **12***b*. In the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye, color filters **13**R, **13**G, **13**B, and **13**Y are provided, respectively.

Herein the liquid crystal layer LC is a liquid crystal layer of vertical alignment type. The electrode **12***a* is disposed on a back substrate **16***a*, and the electrode **12***b* and the color filters **13**R, **13**G, **13**B, and **13**Y are disposed on a front substrate **16***b*. The electrode **12***a* is disposed separately for each sub-pixel, and the electrode **12***b* is disposed in common (continuously) among a plurality of sub-pixels (typically a plurality of pixels P). Although not shown in the figure, on the back substrate **16***a*, a gate bus line, a storage capacitor bus line, an insulating layer, a source bus line, a thin film transistor, an alignment film, and the like are further disposed. On the front substrate **16***b*, an alignment film and the like are further disposed. On the outer sides of the back substrate **16***a* and the front substrate **16***b*, polarizing plates are disposed.

For example, the liquid crystal layer LC contains a nematic liquid crystal material having negative dielectric anisotropy. In combination with the polarizing plates which are arrange in a crossed Nichol manner, display is performed in a normally black mode. In this specification, the liquid crystal layers LC of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye may sometimes be referred to as liquid crystal layers LC_R, LC_G, LC_B, and LC_Y, respectively.

FIG. **1**(*d*) shows a schematic diagram of the backlight **20**. The backlight **20** includes at least one light source unit **22**. Herein, in the backlight **20**, a plurality of light source units **22** are arrange in a matrix having a plurality of rows and a plurality of columns. One light source unit **22** corresponds to a plurality of pixels. For example, in the case of Full Hi-Vision standards, 1920×1080 pixels are provided in the liquid crystal panel **10**, but 1000 to 2000 light source units **22** are provided in the backlight **20**. Alternatively, in the backlight **20**, **100** to **200** light source units **22** may be provided.

FIG. **1**(*e*) shows a schematic diagram of the light source unit **22**. The light source unit **22** includes a red light source **22**R, a green light source **22**G, and a blue light source **22**B. The intensities of light emitted from the red light source **22**R, the green light source **22**G, and the blue light source **22**B can be controlled mutually independently. By controlling the intensities of light respectively emitted from the light sources **22**R, **22**G, and **22**B of the light source unit **22**, the light of the backlight **20** can be changed.

As the red light source **22**R, the green light source **22**G, and the blue light source **22**B, for example, a red light emitting diode (LED), a green light emitting diode, a blue light emitting diode are suitably utilized, respectively. In the following description of this specification, the red light source **22**R, the green light source **22**G, and the blue light source **22**B may sometimes be simply referred to as light sources **22**R, **22**G, and **22**B, respectively.

For example, the backlight **20** may be a direct backlight. Although not shown in the figure, a diffuser may be provided between the liquid crystal panel **10** and the light source unit **22**. Alternatively, the backlight **20** may be a backlight of edge lighting type. Although not shown in the figure, a light guiding plate may be provided between the liquid crystal panel **10** and the light source unit **22**. Such a diffuser or light guiding plate is disposed in the backlight **20**. As described above, in the case where a plurality of light source units **22** are provided, the variation of intensities of light emitted from the light sources **22**R, **22**G, and **22**B may sometimes be relatively large. However, after the light source unit **22** is disposed in the backlight **20**, an electric current or the like supplied to the light sources **22**R, **22**G, and **22**B is finely adjusted, thereby suppressing the variation of intensities of light emitted from the light sources **22**R, **22**G, and **22**B.

The backlight **20** emits light from the light sources **22**R, **22**G, and **22**B to the liquid crystal panel **10**. The intensities of light emitted from the light sources **22**R, **22**G, and **22**B can be arbitrarily controlled. For example, the intensities of light emitted from the light sources **22**R, **22**G, and **22**B are controlled in accordance with the electric current supplied to the light sources **22**R, **22**G, and **22**B. The control of the intensities of light from the light sources **22**R, **22**G, and **22**B is performed by pulse width modulation (PWM). For example, by increasing the duty ratio, the intensities of light from the light sources **22**R, **22**G, and **22**B can be increased. Alternatively, by increasing the amplitude of pulse, the intensities of light from the light sources **22**R, **22**G, and **22**B can be increased. Alternatively, by increasing the duty ratio and also increasing the amplitude of pulse, the intensities of light from the light sources **22**R, **22**G, and **22**B can be increased.

As described above, in this embodiment, a plurality of light source units **22** are disposed in the backlight **20**. In the following description of this specification, in the pixel P of the liquid crystal panel **10**, an area of the pixel P which is irradiated with light from one light source unit **22** is referred to as a light irradiation area. A light irradiation area by a certain light source unit **22** and a light irradiation area by a light source unit **22** which is adjacent thereto are partially overlapped. By controlling the intensity of light emitted from a light source unit **22**, the intensity of light incident on a pixel P in the light irradiation area corresponding to the light source unit **22** of the liquid crystal panel **10** from the backlight **20** is varied. In the case where all pixels P in the light irradiation area display black, the power consumption can be reduced by turning off the light source unit **22**. In addition, by making different the intensities of light source units **22** in the backlight **20**, a high contrast ratio can be easily realized.

As described above, in the liquid crystal display device **100**, the color filters **13**R, **13**G, **13**B, and **13**Y are provided on the front substrate **16***b*. The light emitted from the backlight **20** is transmitted through the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y, and thereafter transmitted through the color filters **13**R, **13**G, **13**B, and **13**Y, thereby performing display of red, green, blue, and yellow. The transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y are varied depending on the voltage applied across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y, i.e., the voltage between the electrode **12***a* and the electrode **12***b*.

The color filters **13**R, **13**G, **13**B, and **13**Y are specific to the liquid crystal panel **10**. In the case where the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y exhibit the minimum value, respectively, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** also exhibit the minimum value. On the contrary, in the case where the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y exhibit the maximum value, respectively, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** also exhibit the maximum value.

FIG. **2** shows transmission spectra of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10**. For example, the transmission spectrum of the red sub-pixel R indicates the transmission spectrum of the liquid crystal panel **10** when the transmittance of the red sub-pixel R is made to be the maximum value, and the transmittances of the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are made to be the minimum value. Specifically, the transmission spectrum of the red sub-pixel R is measured in the condition where the applied voltage across the liquid crystal layer LC_R in the liquid crystal panel **10** is made to be the maximum value, and the applied voltages across the liquid crystal layers LC_G, LC_B, and LC_Y are made to be the minimum value. The transmission spectra of the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are also measured in the same way. In the liquid crystal panel **10**, the red sub-pixel R mainly transmits light having wavelengths of 570 nm or more, and the green sub-pixel G mainly transmits light having wavelengths of 480 nm to 580 nm. The blue sub-pixel B mainly transmits light having wavelengths of 400 nm to 520 nm, and the yellow sub-pixel Ye mainly transmits light having wavelengths of 500 nm or more.

FIG. **3** shows emission spectra of the light sources **22**R, **22**G, and **22**B in the backlight **20**. As described above, the respective intensities of the light sources 22R, 22G, and 22B can be controlled. FIG. 3 shows the emission spectra when the respective intensities of the light sources 22R, 22G, and 22B are made to be the maximum. The peak wavelength of the emission spectrum of the light source 22R is about 450 nm, the peak wavelength of the emission spectrum of the light source 22G is about 520 nm, and the peak wavelength of the emission spectrum of the light source 22B is about 630 nm.

FIG. 4 shows a schematic diagram of the liquid crystal display device 100. As described above, in the backlight 20, the light source unit 22 includes the light sources 22R, 22G, and 22B. The backlight 20 emits light from the light sources 22R, 22G, and 22B to the liquid crystal panel 10. The intensities of light emitted from the light sources 22R, 22G, and 22B can be arbitrarily controlled. Not only the intensity but also the color temperature of the light from the backlight 20 can be controlled.

In this specification, the intensity of the light source 22R which is normalized by the minimum value and the maximum value is indicated by a relative intensity sr. Similarly, the intensities of the light sources 22G and 22B which are normalized by the minimum value and the maximum value are indicated by relative intensities sg and sb, respectively. The minimum value of the respective relative intensities sr, sg, and sb is 0 (zero), and the maximum value thereof is 1. The respective relative intensities sr, sg, and sb are varied in the range of 0 or more and 1 or less. In this specification, in the case where the relative intensities sr, sg, and sb are the minimum value (i.e., 0), the light sources 22R, 22G, and 22B are in the off state, respectively. In the case where the relative intensities sr, sg, and sb are higher than the minimum value (i.e., sr, sg, sb>0), the light sources 22R, 22G, and 22B are in the on state, respectively.

The light emitted from the backlight 20 is varied in accordance with the intensities of the light of the light sources 22R, 22G, and 22B. On the pixel P in a region in which the light irradiation areas by light source units 22 adjacent to each other are overlapped, light of respective light sources 22R, 22G, and 22B of different light source units 22 is incident.

In the following description of this specification, in the light emitted from the backlight 20 to the respective pixels P in the liquid crystal panel 10, the respective intensities from the light sources 22R, 22G, and 22B which are normalized by the minimum value and the maximum value are referred to as relative intensities br, bg, and bb. When the relative intensities sr, sg, and sr are determined, the relative intensities br, bg, and bb are determined accordingly. When the respective relative intensities sr, sg, and sb are 1, the relative intensities br, bg, and bb are 1, respectively. When the respective relative intensities sr, sg, and sb are 0, the relative intensities br, bg, and bb are 0, respectively.

In the case where the relative intensities sr, sg, and sb of the respective light source units 22 are the same, the ratio of the relative intensities br, bg, and bb of the backlight 20 in the pixel P of the liquid crystal panel 10 is substantially the same, but the intensity of light emitted from the backlight 20 in accordance with the pixel P is not necessarily the same. For example, even in the case where the intensities of light emitted from the light sources 22R of the respective light source units 22 are the same, the intensities of light from the light sources 22R in different pixels P are not necessarily the same. Similarly, even in the case where the intensities of light emitted from the light sources 22G and 22B of the respective light source units 22 are the same, the intensities of light from the light sources 22G and 22*b* in different pixels P are not necessarily the same.

In the following description of this specification, in order to prevent the description from being excessively complicated, except for the case especially noted, when the relative intensities sr of the respective light source units 22 are the same, light of the light sources 22 is incident on the respective pixels P in the liquid crystal panel 10 with the same intensity. Similarly, when the relative intensities sg and sr of the respective light source units 22 are the same, the light of the light sources 22G and 22B is incident on the respective pixels P of the liquid crystal panel 10 with the same intensities. In the case where the relative intensities sr, sg, and sb of the respective light source unit 22 are the same, typically, the magnitude correlation among the relative intensities br, bg, and bb of the backlight 20 is the same as the magnitude correlation among the relative intensities sr, sg, and sb of the light sources 22R, 22G, and 22B. For example, the relative intensities br, bg, and bb of the backlight 20 are the same as the relative intensities sr, sg, and sb of the light sources 22R, 22G, and 22B, respectively.

As described above, in the liquid crystal panel 10, the pixel P includes the red, green, blue, and yellow sub-pixels R, G, B, and Ye. In this specification, grayscale levels of red, green, blue, and yellow of the liquid crystal panel 10 are indicated by p_R, p_G, p_B, and p_Y. The grayscale levels p_R, p_G, p_B, and p_Y correspond to the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the red, green, blue, and yellow sub-pixels R, G, B, and Ye. Specifically, across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the red, green, blue, and yellow sub-pixels R, G, B, and Ye, voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_Y are applied, so that the transmittances of the red, green, blue, and yellow sub-pixels R, G, B, and Ye are changed. As described above, in the liquid crystal display device 100 in this embodiment, it is noted that the intensity of light from the backlight 20 is varied, so that the grayscale level of the liquid crystal panel 10 does not necessarily agree with the grayscale level of the liquid crystal display device 100.

In the case where the liquid crystal panel 10 is of the normally black type, the transmittances exhibit the minimum value when the lowest applied voltage (typically, the voltage of zero) is applied to the respective liquid crystal layers LC_R, LC_G, LC_B, and LC_Y, and the transmittances exhibit the maximum value when the highest applied voltage is applied to the respective liquid crystal layers LC_R, LC_G, LC_B, and LC_Y. In the case where the applied voltage across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y is low, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are low. In the case where the applied voltage across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y is high, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are high.

As described above, the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel 10 correspond to the transmittances of the red, green, blue, and yellow sub-pixels R, G, B, and Ye in the liquid crystal panel 10. In the following description of this specification, the transmittances of which the minimum value and the maximum value in the respective red, green, blue, and yellow sub-pixels R, G, B, and Ye are normalized to be zero (0) and 1, respectively, are represented by relative transmittances p_R, p_G, p_B, and p_Y. In the case where the intensity of light from the backlight 20 is constant, the grayscale levels p_R, p_G, p_B, and p_Y are non-linear with respect to the luminance (or the intensity of emitted light), but the relative transmittances p_R, p_G, p_B, and p_Y are linear with respect to the luminance (or the intensity of emitted light).

The light emitted from the light sources **22**R, **22**G, and **22**B in the backlight **20** is transmitted through the red, green, blue, and yellow sub-pixels R, G, B, and Ye in the liquid crystal panel **10**, and then emitted from the red, green, blue, and yellow sub-pixels R, G, B, and Ye. The light emitted from the red, green, blue, and yellow sub-pixels R, G, B, and Ye reaches an observer, and luminance corresponding to the intensity of emitted light is exhibited. In the red, green, blue, and yellow sub-pixels R, G, B, and Ye, the luminance is increased as the intensity of emitted light becomes higher, and the luminance is lowered as the intensity of emitted light becomes lower.

The intensity of light emitted from each pixel P of the liquid crystal panel **10** is expressed by the product of the intensity of light emitted from the backlight **20** and the transmittance of the liquid crystal panel **10**. For example, the intensity of light emitted from each pixel P of the liquid crystal panel **10** is expressed by the sum of the intensities of light emitted from the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye.

Specifically, the light emitted from the red sub-pixel R is mainly the light emitted from the light source **22**R in the backlight **20** and then transmitted through the liquid crystal layer LC_R and the color filter **13**R in the liquid crystal panel **10**. Accordingly, the intensity of light emitted from the red sub-pixel R is mainly expressed by the product of the intensity of light of the light source **22**R in the backlight **20** and the transmittance of the red sub-pixel R. The transmittance of the red sub-pixel R is mainly expressed by the product of the transmittance of the color filter **13**R and the transmittance of the liquid crystal layer LC_R.

Similarly, the light emitted from the green sub-pixel G is mainly the light emitted from the light source **22**G in the backlight **20** and then transmitted through the liquid crystal layer LC_G and the color filter **13**G in the liquid crystal panel **10**. Accordingly, the intensity of light emitted from the green sub-pixel G is mainly expressed by the product of the intensity of light of the light source **22**G in the backlight **20** and the transmittance of the green sub-pixel G. The transmittance of the green sub-pixel G is mainly expressed by the product of the transmittance of the color filter **13**G and the transmittance of the liquid crystal layer LC_G.

The light emitted from the blue sub-pixel B is mainly the light emitted from the light source **22**B in the backlight **20** and then transmitted through the liquid crystal layer LC_B and the color filter **13**B in the liquid crystal panel **10**. Accordingly, the intensity of light emitted from the blue sub-pixel B is mainly expressed by the product of the intensity of light of the light source **22**B in the backlight **20** and the transmittance of the blue sub-pixel B. The transmittance of the blue sub-pixel B is mainly expressed by the product of the transmittance of the color filter **13**B and the transmittance of the liquid crystal layer LC_B.

The light emitted from the yellow sub-pixel Ye is mainly the light emitted from the light sources **22**R and **22**G in the backlight **20** and then transmitted through the liquid crystal layer LC_Y and the color filter **13**Y in the liquid crystal panel **10**. Accordingly, the intensity of light emitted from the yellow sub-pixel Ye is mainly expressed by the product of the sum of the intensities of light of the light sources **22**R and **22**G in the backlight **20** and the transmittance of the yellow sub-pixel Ye. The transmittance of the yellow sub-pixel Ye is mainly expressed by the product of the transmittance of the color filter **13**Y and the transmittance of the liquid crystal layer LC_Y.

The grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** and the relative intensities br, bg, and bb of the backlight **20** are set in accordance with an input video signal. The input video signal is a signal which can be utilized for a cathode ray tube (CRT) with gamma value of 2.2, for example, and is conformed to NTSC (National Television Standards Committee) standards or PAL (Phase Alternating Line) standards. The input video signal indicates red, green, and blue grayscale levels r, g, and b. In general, the grayscale levels r, g, and b are represented by 8 bits. Alternatively, the input video signal has a value which can be converted into the red, green and blue grayscale levels r, g, and b. The value thereof is expressed in three dimensions. For example, the input video signal is YCrCb signal. In the case where the input video signal is conformed to the BT.709 standards, the grayscale levels r, g, and b of the input video signal are within the range from the lowest grayscale level (e.g. the grayscale level of 0) to the highest grayscale level (e.g. the grayscale level of 255), respectively. In the following description, the grayscale levels r, g, and b of the input video signal mean not only the grayscale levels indicated in the input video signal itself, but also the grayscale levels obtained by converting the values indicated in the input video signal.

The grayscale levels r, g, and b of the input video signal have non-linear relationships with respect to the luminance of red, green, and blue. In this specification, the grayscale levels r, g, and b of the input video signal are converted so as to have linear relationships with respect to the luminance of red, green, and blue in accordance with predetermined relationships, and such converted grayscale levels are also referred to as luminance levels r, g, and b. The luminance levels r, g, and b are normalized by the minimum value and the maximum value of respective luminance of red, green, and blue. In the case where the respective luminance of red, green, and blue indicates the maximum luminance, the luminance level is 1. In the case where the respective luminance indicates the minimum luminance, the luminance level is 0 (zero). The grayscale levels r, g, and b are non-linear with respect to the luminance, but the luminance levels r, g, and b are linear with respect to the luminance. The magnitude correlation among the grayscale levels r, g, and b is the same as that of the luminance levels r, g, and b.

Typically, in the case where the input video signal indicates white, the light of the respective light sources **22**R, **22**G, and **22**B in the backlight **20** exhibits the highest intensity, and the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** exhibit the maximum values, respectively. In this case, the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye exhibit the maximum luminance, respectively.

Table 1 shows luminance ratios of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal display device **100**. The luminance ratio of the red sub-pixel R indicates the ratio of the luminance of the red sub-pixel R to the luminance of the pixel P when white (W) is displayed. Specifically, the luminance ratio of the red sub-pixel R is the luminance ratio in the case where the red sub-pixel R exhibits the highest transmittance and the other sub-pixels (i.e., the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye) exhibit the lowest transmittances with respect to the luminance when white (W) is displayed. Similarly, the luminance ratios of the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are the luminance ratios in the case where the corresponding sub-pixel exhibits the highest transmittance and the other sub-pixels exhibit the lowest transmittances with respect to the luminance when white (W) is displayed.

TABLE 1

	Luminance Ratio
R	10.7%
G	33.8%
B	11.8%
Ye	43.7%
W	100%

Typically, in the case where the input video signal indicates black, the relative intensities of the respective light sources **22**R, **22**G, and **22**B in the backlight **20** indicate the minimum values, and the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** indicate the minimum value, respectively. In this case, the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye exhibit the lowest luminance, respectively.

In the liquid crystal display device **100** in this embodiment, each pixel P in the liquid crystal panel **10** includes four or more sub-pixels for displaying colors which are different from each other, and each light source unit **22** includes light sources **22**R, **22**G, and **22**B. Accordingly, display can be performed in wide color reproduction range. In addition, depending on the change of colors to be displayed, not only the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y in the liquid crystal panel **10** are changed, but also the relative intensities of the light sources **22**R, **22**G, and **22**B of each light source unit **22** in the backlight **20** can be changed. Thus it is possible to improve the contrast ratio and realize the reduction in power consumption.

Specifically, in the case where the liquid crystal display device **100** displays red, the light source **22**R in the backlight **20** is turned on, and the light sources **22**G and **22**B are turned off. In the liquid crystal panel **10**, the red sub-pixel R transmits light, and the other sub-pixels block out the light. Similarly, in the case where the liquid crystal display device **100** displays green, the light source **22**G is turned on, and the light sources **22**R and **22**B are turned off. In the liquid crystal panel **10**, the green sub-pixel G transmits light, and the other sub-pixels block out the light. Similarly, in the case where the liquid crystal display device **100** displays blue, the light source **22**B is turned on, and the light sources **22**R and **22**G are turned off. In the liquid crystal panel **10**, the blue sub-pixel B transmits light, and the other sub-pixels block out the light. In the case where the liquid crystal display device **100** displays yellow, the light sources **22**R and **22**G are turned on, and the light source **22**B is turned off. In the liquid crystal panel **10**, the yellow sub-pixel Ye transmits light, and the other sub-pixels block out the light. As described above, in accordance with the colors to be displayed on the liquid crystal display device **100**, the turning on and off of the light sources **22**R, **22**G, and **22**B are controlled, thereby reducing the power consumption. In addition, in accordance with the colors to be displayed on the liquid crystal display device **100**, not only the transmittances of the red, green, blue, and yellow sub-pixels R, G, B, and Ye are changed, the intensities of light emitted from the light sources **22**R, **22**G, and **22**B are controlled, thereby realizing high contrast ratio.

For example, in the case where the liquid crystal display device **100** displays green, the light of the light source **22**G is emitted from the backlight **20**, and the green sub-pixel G in the liquid crystal panel **10** transmits the light. Herein the grayscale levels (r, g, b) of the input video signal are represented by (0, 255, 0) in the 255 grayscale notation.

FIG. **5**(*a*) shows the emission spectrum of the backlight **20**. Herein the relative intensities (sr, sg, sb) of the light sources **22**R, **22**G, and **22**B are (0, 1, 0), the light source **22**G is in the on state, and the emission spectrum has the peak wavelength of about 520 nm.

FIG. **5**(*b*) shows the transmission spectrum of the liquid crystal panel **10**. Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 0), and light having wavelengths of 480 nm to 580 nm is mainly transmitted through the green sub-pixel G.

FIG. **5**(*c*) shows the emission spectrum of the liquid crystal display device **100** in the case where the light of the spectrum shown in FIG. **5**(*a*) is emitted from the backlight **20**, and the light of the spectrum shown in FIG. **5**(*b*) is transmitted in the liquid crystal panel **10**. As described above, the intensity of light emitted from the green sub-pixel G is mainly expressed by the product of the intensity of light of the light source **22**G in the backlight **20** and the transmittance of the green sub-pixel G. The emission spectrum also has the peak wavelength of about 520 nm.

As described above, in the case where the grayscale levels (r, g, b) of the input video signal are (0, 255, 0), the light sources **22**R and **22**B of the backlight **20** are turned off, and the light source **22**G is turned on. The relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). Table 2 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 2

Embodiment 1	br	bg	bb
Relative intensity of Backlight	0	1	0

The grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 0) in the 255 grayscale notation. Table 3 shows the grayscale levels of the liquid crystal panel **10**. The grayscale level of 0 corresponds to the minimum value, and the grayscale level of 255 corresponds to the maximum value.

TABLE 3

Embodiment 1	Red sub-pixel	Green sub-pixel	Blue sub-pixel	Yellow sub-pixel
Grayscale level of Liquid crystal panel	0	255	0	0

As described above, in the liquid crystal display device **100**, the grayscale levels (p_R, p_G, p_B, p_Y) of the red, green, blue, and yellow sub-pixels R, G, B, and Ye in the liquid crystal panel **10** are (0, 255, 0, 0), and the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), so that the ratio of luminance of the liquid crystal display device **100** with respect to the luminance of white display is 0.325. In the following description of this specification, such ratio is sometimes referred to as a normalized luminance. The luminance ratio of the green sub-pixel G shown in Table 1 is 33.8% (0.338), and the luminance ratio is higher than the normalized luminance when green is displayed on the liquid crystal display device **100**. The luminance ratio of the green sub-pixel G is a value obtained by turning on not only the light source **22**G but also the light sources **22**R and **22**B. On the contrary, the normalized luminance is a value obtained by turning on only the light source **22**G and by turning off the light sources **22**R and **22**B.

As described above, in the liquid crystal display device **100** in this embodiment, a plurality of light source units **22** are provided in the backlight **20**. In the case where all of the pixels P in a specific light irradiation area display black, the light sources 22R, 22G, and 22B of the light source units 22 corresponding to the specific light irradiation area are respectively turned off, thereby suppressing the power consumption of the backlight 20. In addition, the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the light irradiation area are made to be the minimum value, so that the light leakage can be suppressed. As a result, the contrast ratio can be increased.

Alternatively, for example, in the case where all of the pixels P in a specific light irradiation area display red, the light sources 22R of the light source units 22 corresponding to the light irradiation area are turned on, and the light sources 22G and the light sources 22B are turned off, thereby suppressing the power consumption of the backlight 20. A voltage is applied across the liquid crystal layer LC_R of the red sub-pixel R in the light irradiation area, so that the transmittance of the liquid crystal layer LC_R is made to have a predetermined value, and the transmittances of the liquid crystal layers LC_G, LC_B, and LC_Y of the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye are made to have the minimum value, thereby suppressing the light leakage and increasing the contrast ratio.

The input video signal indicates a color of respective color display pixels in a frame or a field. In this specification, in order to prevent the description from being excessively complicated, except for the case to be especially mentioned, the input video signal is described in such a condition that all of the pixels indicate the same color over a plurality of vertical scanning periods.

For example, the control of the liquid crystal panel 10 and the backlight 20 is performed in the following way. Hereinafter the liquid crystal display device 100 will be described with reference to FIG. 6. The liquid crystal display device 100 includes a control circuit 30 that controls the liquid crystal panel 10 and the backlight 20. The control circuit 30 generates a light source driving signal and a panel driving signal based on the input video signal.

The backlight 20 is driven based on the light source driving signal generated in the control circuit 30. The light source driving signal indicates the relative intensities sr, sg, and sb of the light sources 22R, 22G, and 22B in the backlight 20. By the light source driving signal, the light sources 22R, 22G, and 22B emit light with the relative intensities sr, sg, and sb. In this case, light is emitted from the backlight 20 with relative intensities br, bg, and bb.

The liquid crystal panel 10 is driven based on the panel driving signal generated in the control circuit 30. The panel driving signal indicates the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel 10. The grayscale levels p_R, p_G, p_B, and p_Y correspond to applied voltages across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the red, green, blue, and yellow sub-pixels R, G, B, and Ye in the liquid crystal panel 10. Specifically, voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_Y are applied across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y, thereby changing the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y. In this way, in the liquid crystal display device 100, the relative intensities br, bg, and bb of the backlight 20 are changed, and the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the red, green, blue, and yellow sub-pixels R, G, B, and Ye are changed, so that the color display pixels P can display various colors.

FIG. 7 shows a specific configuration of the control circuit 30. The control circuit 30 includes an active drive processing portion 32, a multi-primary color converting portion 34, a panel driving circuit 36, and a backlight driving circuit 38. As described above, herein the backlight 20 includes a plurality of light source units 22, and each light source unit 22 corresponds to a corresponding light irradiation area of the liquid crystal panel 10. As a result, as for the backlight 20, the light intensity can be controlled for each area of the liquid crystal panel 10. Such an active drive processing portion 32 is also referred to as an area active drive processing portion.

The active drive processing portion 32 generates a light source signal and a liquid crystal data signal based on the input video signal. The light source signal indicates the relative intensities sr, sg, and sb of the light sources 22R, 22G, and 22B. For example, the active drive processing portion 32 sets the relative intensities sr, sg, and sb of the light sources 22R, 22G, and 22B, based on the respective mean values of the grayscale levels r, g, and b of the input video signal and/or the maximum value thereof. As described above, herein all pixels exhibit the same color in the input video signal, and the grayscale levels r, g, and b corresponding to different pixels are also equal to each other.

The liquid crystal data signal indicates the red, green, and blue grayscale levels pr, pg, and pb. Although the details will be described later, the grayscale levels pr, pg, and pb of the liquid crystal data signal are set based on the grayscale levels r, g, and b and the relative intensities sr, sg, and sb, for example. In many cases, the grayscale levels pr, pg, and pb of the liquid crystal data signal are different from the grayscale levels r, g, and b of the input video signal.

The grayscale levels pr, pg, and pb correspond to the grayscale levels of the red, green, and blue sub-pixels of a three-primary color liquid crystal panel. When the liquid crystal data signal of the grayscale levels pr, pg, and pb is input into the three-primary color liquid crystal panel, the liquid crystal layers of the red, green, and blue sub-pixels of the liquid crystal panel exhibit the transmittances corresponding to the grayscale levels pr, pg, and pb. In the following description of this specification, in each of the red, green and blue sub-pixel of the three-primary color liquid crystal panel, the transmittance normalized in such a manner that the minimum value is zero (0) and the maximum value is 1 is referred to as a transmittance level. That is, the transmittance level of 0 corresponds to the minimum value of the transmittance of each of the red, green, and blue sub-pixels in the three-primary color liquid crystal panel, and the transmittance level of 1 corresponds to the maximum value of the transmittance of each of the red, green, and blue sub-pixels in the three-primary color liquid crystal panel. The grayscale levels pr, pg, and pb are non-linear with respect to the luminance (or the intensity of emitted light), but the transmittance levels pr, pg, and pb are linear with respect to the luminance (or the intensity of emitted light).

Thus, the active drive processing portion 32 generates a light source signal indicating the relative intensities sr, sg, and sb and a liquid crystal data signal indicating the grayscale levels pr, pg, and pb based on the input video signal which indicates the grayscale levels r, g, and b. Herein the luminance levels r, g, and b of the input video signal are expressed by the relative intensities br, bg, and bb of the backlight 20 and the transmittance levels pr, pg, and pb of the liquid crystal data signal. Specifically, the luminance level r is expressed by the product of the relative intensity br and the transmittance level pr. Similarly, the luminance level g is expressed by the product of the relative intensity bg and the transmittance level pg, and the luminance level b is expressed by the product of the relative intensity bb and the transmittance level pb.

The multi-primary color converting portion 34 generates a panel signal from the liquid crystal data signal. The above-described liquid crystal panel 10 performs display with four primary colors, so that a panel signal indicating grayscale levels of four primary colors is generated. Specifically, the multi-primary color converting portion **34** converts the grayscale levels pr, pg, and pb of the liquid crystal data signal into the red, green, blue, and yellow grayscale levels p_1, p_2, p_3, and p_4 of the panel signal. Herein the color phase of color represented by the grayscale levels pr, pg, and pb before the conversion is substantially the same as the color phase of color represented by the grayscale levels p_1, p_2, p_3, and p_4 after the conversion. Thereafter, the multi-primary color converting portion **34** generates a panel signal which indicates the grayscale levels p_1, p_2, p_3, and p_4 as the grayscale levels p_R, p_G, p_B, and p_Y.

The panel driving circuit **36** generates a panel driving signal based on the panel signal, thereby driving the liquid crystal panel **10**. Voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_Y are applied across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the liquid crystal panel **10**, and the red, green, blue, and yellow sub-pixels R, G, B, and Ye of the liquid crystal panel **10** exhibit the transmittances corresponding to the gray scale levels p_R, p_G, p_B, and p_Y. The backlight driving circuit **38** generates a light source driving signal based on the light source signal. The light sources **22**R, **22**G, and **22**B of the backlight **20** are driven by the light source driving signal. In this specification, the grayscale levels r, g, and b of the input video signal, the grayscale levels pr, pg, and pb of the liquid crystal data signal and/or the grayscale levels p_R, p_G, p_B, and p_Y of the panel signal mean not only the grayscale levels indicated in the input video signal, the liquid crystal data signal, and/or the panel signal themselves, but also the grayscale levels obtained by converting the values indicated in the input video signal, the liquid crystal data signal, and/or the panel signal.

In FIG. **7**, the active drive processing portion **32** and the multi-primary color converting portion **34** are shown as different components. Alternatively, the active drive processing portion **32** and the multi-primary color converting portion **34** may be included in a signal processing portion **33** which is embodied as a single circuit chip. In this case, the signal processing portion **33** generates a light source signal and a panel signal based on the input video signal.

The luminance of red displayed on the liquid crystal display device **100** is mainly related to the relative intensity br of the backlight **20** and the grayscale level (the transmittance level) p_R of the liquid crystal panel **10**. The luminance of green displayed on the liquid crystal display device **100** is mainly related to the relative intensity bg of the backlight **20** and the grayscale level (the transmittance level) p_G of the liquid crystal panel **10**. The luminance of blue displayed on the liquid crystal display device **100** is mainly related to the relative intensity bb of the backlight **20** and the grayscale level (the transmittance level) p_B of the liquid crystal panel **10**. The luminance of yellow displayed on the liquid crystal display device **100** is mainly related to the relative intensities br and bg of the backlight **20** and the grayscale level (the transmittance level) p_Y of the liquid crystal panel **10**.

In the above description, in the case where the liquid crystal display device **100** displays black, the relative intensities of the light sources **22**R, **22**G, and **22**B in the backlight **20** exhibit the minimum value, respectively, and the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** exhibit the minimum value, respectively. However, the present invention is not limited to this. Alternatively, in the case where the liquid crystal display device **100** displays black, irrespective of the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye, the relative intensities br, bg, and bb of the backlight **20** may exhibit the minimum value, respectively. Alternatively, in the case where the liquid crystal display device **100** displays black, irrespective of the relative intensities br, bg, and bb of the backlight **20**, the grayscale levels p_R, p_G, p_B, and p_Y in the liquid crystal panel **10** may exhibit the minimum value, respectively.

Strictly, even if the light sources **22**R, **22**G, and **22**B of the backlight **20** are turned off, part of light emitted from a light source of another light source unit **22** may sometimes be transmitted through the liquid crystal panel **10**. Similarly, even if the grayscale levels p_R, p_G, p_B, and p_Y in the liquid crystal panel **10** are the minimum value, respectively, the light emitted from the light sources **22**R, **22**G, and **22**B of the backlight **20** may be transmitted through the liquid crystal panel **10**. For these reasons, in the case where the input video signal indicates black, it is preferred that the relative intensities of the light sources **22**R, **22**G, and **22**B of the backlight **20** may exhibit the minimum value, respectively, and the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10** may exhibit the minimum value, respectively. Accordingly, it is possible to realize high contrast ratio.

As described above, the luminance level r of the input video signal is expressed by the product of the relative intensity br of the backlight **20** and the transmittance level pr of the liquid crystal data signal. In the case where the luminance level r of the input video signal is a median value, a plurality of combinations of the relative intensity br and the transmittance level pr are considered. However, if the transmittance level pr of the liquid crystal data signal is the maximum value, the relative intensity br can be lowered. As a result, the power consumption of the light source **22**R can be reduced. Similarly, in the case where the luminance levels g and b of the input video signal are median values, when the transmittance levels pg and pb in the liquid crystal data signal are made to have the maximum value, the relative intensities bg and bb can be lowered. As a result, the power consumption of the light sources **22**G and **22**B can be reduced.

In the liquid crystal display device **100**, it is preferred that the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** and the relative intensities br, bg, and bb of the backlight **20** may be set in the following way based on the grayscale levels r, g, and b of the input video signal.

For example, in the case where the grayscale level r of the input video signal is higher than the minimum value, the relative intensity br of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_R of the liquid crystal panel **10** is made to be the maximum value. Accordingly, the power consumption can be reduced. In the case where the grayscale level r is the minimum value, the relative intensity br of the backlight **20** is made to be the minimum value, and the grayscale level p_R is made to be the minimum value. Accordingly, the power consumption can be reduced, and the contrast ratio can be improved.

In the case where the grayscale level g of the input video signal is higher than the minimum value, the relative intensity bg of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_G of the liquid crystal panel **10** is made to be the maximum value. In the case where the grayscale level g is the minimum value, the relative intensity bg of the backlight **20** is set to be the minimum value, and the grayscale level p_G of the liquid crystal panel **10** is made to be the minimum value. Similarly, in the case where the grayscale level b of the input video signal is higher than the minimum value, the relative intensity bb of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_B

of the liquid crystal panel **10** is made to be the maximum value. In the case where the grayscale level b is the minimum value, the relative intensity bb of the backlight **20** is made to be the minimum value, and the grayscale level p_B of the liquid crystal panel **10** is made to be the minimum value.

In the case where both of the grayscale levels r and g of the input video signal are higher than the minimum value, as is understood from the above description, both of the relative intensities br and bg of the backlight **20** are higher than the minimum value, and the grayscale level p_Y of the liquid crystal panel **10** is made to be the maximum value. Accordingly, the power consumption can be reduced. In the case where at least one of the grayscale levels r and g of the input video signal is the minimum value, as is understood from the above description, at least one of the relative intensities br and bg of the backlight **20** is made to be the minimum value, and the grayscale level p_Y of the liquid crystal panel **10** is made to be the minimum value. Accordingly, the power consumption can be reduced, and additionally the contrast ratio can be improved.

As described above, in the case where any one of the grayscale levels r, g, and b of the input video signal is the minimum value, the corresponding one of the relative intensities br, bg, and bb of the backlight **20** is also the minimum value, so that the corresponding one of the light sources **22**R, **22**G, and **22**B is turned off. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the relative intensities br, bg, and bb of the backlight **20** are higher than the minimum value, and the light sources **22**R, **22**G, and **22**B are turned on. In the case where any one of the grayscale levels r, g, and b of the input video signal has the minimum value, the corresponding one of the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** also has the minimum value. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** have the maximum value.

In the liquid crystal display device **100**, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is set to be the same as the magnitude correlation among the luminance levels r, g, and b of the input video signal. For example, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b of the input video signal, respectively. In addition, the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** are set depending on the condition whether the grayscale levels r, g, and b of the input video signal are the minimum value or not. In the case where the grayscale levels r, g, and b are the minimum value, the grayscale levels p_R, p_G, and p_B exhibit the minimum value. In the case where the grayscale levels r, g, and b are higher than the minimum value, the grayscale levels p_R, p_G, and p_B exhibit the maximum value. In the case where at least one of the grayscale levels r and g is the minimum value, the grayscale level p_Y exhibits the minimum value. In the case where both of the grayscale levels r and g are higher than the minimum value, the grayscale level p_Y exhibit the maximum value. For example, in the case where the grayscale levels (r, g, b) of the input video signal are (128, 128, 128), i.e., in the case where the normalized luminance is 0.216 in the input video signal, the grayscale levels (p_R, p_G, p_B, p_Y) are (255, 255, 255, 255), and the relative intensities (br, bg, bb) of the backlight **20** are (0.216, 0.216, 0.216).

FIG. **7** is referred to again. As described above, the active drive processing portion **32** generates a light source signal based on the input video signal. The light source signal indicates the relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B. The backlight driving circuit **38** generates a light source driving signal based on the light source signal. The light sources **22**R, **22**G, and **22**B of the backlight **20** are driven by the light source driving signal. At this time, the light sources **22**R, **22**G, and **22**B emit light with the relative intensities sr, sg, and sb. The relative intensities of the backlight **20** are br, bg, and bb. In the case where any one of the grayscale levels r, g, and b of the input video signal is the minimum value, the corresponding one of the light sources **22**R, **22**G, and **22**B is turned off, and the corresponding one of the relative intensities br, bg, and bb of the backlight **20** has the minimum value. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the light sources **22**R, **22**G, and **22**B are turned on, and the relative intensities br, bg, and bb of the backlight **20** exhibit values higher than the minimum value, respectively.

For example, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is the same as the magnitude correlation among the luminance levels r, g, and b of the input video signal. Specifically, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of br>bg>bb. In the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r<g<b, the relative intensities br, bg, and bb satisfy the relationship of br<bg<bb.

The liquid crystal data signal indicates red, green, and blue grayscale levels pr, pg, and pb. The grayscale levels pr, pg, and pb of the liquid crystal data signal are set, for example, based on the grayscale levels r, g, and b and the relative intensities br, bg, and bb. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, respectively, the grayscale levels pr, pg, and pb of the liquid crystal data signal exhibit the maximum value. In the case where any one of the grayscale levels r, g, and b of the input video signal is the minimum value, the corresponding one of the grayscale levels pr, pg, and pb exhibits the minimum value.

The multi-primary color converting portion **34** generates a panel signal from the liquid crystal data signal. The multi-primary color converting portion **34** converts the grayscale levels pr, pg, and pb of the liquid crystal data signal into the red, green, blue, and yellow grayscale levels p_1, p_2, p_3, and p_4, and generates a panel signal which indicates the grayscale levels p_1, p_2, p_3, and p_4 as the grayscale levels p_R, p_G, p_B, and p_Y.

The panel driving circuit **36** generates a panel driving signal based on the panel signal, thereby driving the liquid crystal panel **10**. The voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_Y are applied across the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the liquid crystal panel **10**.

In the above description, the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** are set in accordance with the grayscale levels r, g, and b of the input video signal. However the present invention is not limited to this. The relative intensities br, bg, and bb of the backlight **20** are set in accordance with the grayscale levels r, g, and b of the input video signal, so that the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** may be set to be the maximum value irrespective of the grayscale levels r, g, and b of the input video signal. It is noted that if the grayscale levels p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** are set in accordance with the grayscale levels r, g, and b of the input video signal, it is possible to easily realize high contrast ratio.

Next, with reference to FIG. **8**, the relative transmittance of the liquid crystal panel **10** and the relative intensity of the backlight **20** in the liquid crystal display device **100** will be described. FIG. **8** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100**.

Herein the input video signal indicates green. For example, the grayscale levels (the luminance levels) r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) are (0, 0.216, 0), and the grayscale levels (r, g, b) are (0, 128, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. As described above, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is the same as the magnitude correlation among the luminance levels r, g, and b of the input video signal, and the relative intensities br, bg, and bb satisfy the relationship of bg>br=bb=0. For example, the relative intensities (br, bg, bb) are (0, 0.216, 0).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (0, 255, 0) in the 255 grayscale notation. As described above, the luminance level r is expressed by the product of the relative intensity br and the transmittance level pr. Similarly, the luminance level g is expressed by the product of the relative intensity bg and the transmittance level pg, and the luminance level b is expressed by the product of the relative intensity bb and the transmittance level pb.

The transmittance levels pr, pg, and pb are converted into the relative transmittances p_R, p_G, p_B, and p_Y by multi-primary color conversion. In this case, the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (0, 255, 0, 0) in the 255 grayscale notation. Thus, the relative intensities br, bg, and bb of the backlight **20** are substantially the same as the luminance levels r, g, and b of the input video signal. Among the luminance levels r, g, and b of the input video signal, transmittance levels pr, pg, and pb corresponding to luminance levels r, g, and b of the input video signal having the minimum value have the minimum value, and transmittance levels pr, pg, and pb corresponding to luminance levels r, g, and b higher than the minimum value have the maximum value. Accordingly, the power consumption of the backlight **20** can be reduced, and the contrast ratio can be increased.

Hereinafter the advantages of the liquid crystal display device **100** in this embodiment will be described as compared with liquid crystal display devices **700** and **800** in comparative examples 1 and 2. First, with reference to FIG. **9**, the liquid crystal display device **700** in the comparative example 1 will be described.

FIG. **9**(*a*) shows a schematic diagram of the liquid crystal display device **700** in the comparative example 1. The liquid crystal display device **700** includes a liquid crystal panel **710** and a backlight **720**.

FIG. **9**(*b*) shows a schematic diagram of the liquid crystal panel **710**. In the liquid crystal panel **710**, a pixel P includes a red sub-pixel R, a green sub-pixel G, and a blue sub-pixel B, and the liquid crystal panel **710** performs display with three primary colors. Such a liquid crystal panel **710** is also referred to as a three primary color panel. The size and the resolution of the liquid crystal panel **710** are substantially the same as those of the liquid crystal panel **10**. The size of the pixel P of the liquid crystal display device **700** is the same as that of the pixel P of the liquid crystal display device **100**.

The backlight **720** emits light of constant intensity in the driving of the liquid crystal display device **700**. In the case where the liquid crystal display device **700** displays white, liquid crystal layers LC_R, LC_G, and LC_B exhibit the maximum transmittances, respectively in the liquid crystal panel **710**. In the case where the liquid crystal display device **700** displays black, the liquid crystal layers LC_R, LC_G, and LC_B exhibit the minimum transmittances, respectively in the liquid crystal panel **710**. Thus, in the liquid crystal display device **700**, in accordance with the change of colors indicated by the input video signal, the transmittances of the liquid crystal layers LC_R, LC_G, and LC_B of respective sub-pixels in the liquid crystal panel **710** are varied, thereby representing various colors.

Table 4 shows the luminance ratios of the red sub-pixel R, the green sub-pixel G, and the blue sub-pixels B in the liquid crystal display device **700** in the comparative example 1. For example, the luminance ratio of the red sub-pixel R shows the ratio of luminance in which the red sub-pixel R exhibits the maximum transmittance and the other sub-pixels (i.e., the green sub-pixel G and the blue sub-pixel B) exhibit the minimum transmittance with respect to the luminance when white (W) is displayed. Similarly, the luminance ratio of each of the green sub-pixel G and the blue sub-pixel B shows the ratio of luminance in which the corresponding sub-pixel exhibits the maximum transmittance and the other sub-pixels exhibit the minimum transmittance with respect to the luminance when white (W) is displayed. As described above, the backlight **720** emits light of constant intensity in the driving of the liquid crystal display device **700**.

TABLE 4

	Luminance Ratio
R	24.6%
G	56.6%
B	18.8%
W	100%

FIG. **10** shows the luminance levels r, g and b of the input video signal, the relative intensities br, bg, and bb of the backlight **720**, and the relative transmittances pr, pg, and pb of the liquid crystal panel **710**, in the liquid crystal display device **700**.

Herein the input video signal indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0. The luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), and the grayscale levels (r, g, b) are (0, 128, 0) in the 255 grayscale notation. In the liquid crystal display device **700**, the backlight **720** emits light of constant intensity irrespective of the color indicated in the input video signal. Herein the relative intensities (br, bg, bb) of the backlight **720** are indicated by (1, 1, 1).

In the liquid crystal display device **700**, the relative transmittances (the grayscale levels) pr, pg, and pb of the liquid crystal panel **710** are equal to the luminance levels (the grayscale levels) r, g, and b of the input video signal. Accordingly, as described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the relative transmittances pr, pg, and pb of the liquid crystal panel **710** satisfy the relationship of pg>pr=pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), the relative transmittances (pr, pg, pb) of the liquid crystal panel **710** are (0, 0.216, 0).

In the liquid crystal display device **700**, voltages corresponding to the transmittance levels (pr, pg, pb) are applied across the liquid crystal layers. Accordingly, in the liquid crystal display device **700**, the grayscale levels of red, green, and blue are (0, 128, 0).

Next, with reference to FIG. **11**, the liquid crystal display device **800** in the comparative example 2 will be described. FIG. **11**(*a*) shows a schematic diagram of the liquid crystal display device **800** in the comparative example 2. The liquid crystal display device **800** includes a liquid crystal panel **810**, and a backlight **820**.

FIG. **11**(*b*) shows a schematic diagram of the liquid crystal panel **810**. Similarly to the liquid crystal panel **10**, in the liquid crystal panel **810**, a pixel P includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a yellow sub-pixel Ye, The liquid crystal panel **810** performs display with four primary colors. The size and the resolution of the liquid crystal panel **810** are substantially the same as those of the liquid crystal panel **710**, and the size of the pixel P of the liquid crystal display device **800** is the same as that of the pixel P of the liquid crystal display device **700**.

The backlight **820** emits light of constant intensity in the driving of the liquid crystal display device **800**. In the case where the liquid crystal display device **800** displays white, liquid crystal layers LC_R, LC_G, LC_B, and LC_Y exhibit the maximum transmittances, respectively. In the case where the liquid crystal display device **800** displays black, the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y exhibit the minimum transmittances, respectively. Thus, in the liquid crystal display device **800**, in accordance with the change of colors indicated in the input video signal, the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_Y of the liquid crystal panel **810** are varied, and the luminance of the respective sub-pixels is changed, thereby representing various colors.

The control of the liquid crystal panel **810** and the backlight **820** is performed in the following manner. FIG. **11**(*c*) shows the liquid crystal display device **800** provided with a control circuit **830**. The control circuit **830** includes a multi-primary color converting portion **834**, a panel driving circuit **836**, and a backlight driving circuit **838**. The multi-primary color converting portion **834** converts grayscale levels r, g, and b of an input video signal into grayscale levels p_R, p_G, p_B, and p_Y of a panel signal. Generally, the color phase of color represented by the grayscale levels r, g, and b of the input video signal is substantially the same as the color phase of color represented by the grayscale levels p_R, p_G, p_B, and p_Y of the panel signal. The backlight driving circuit **838** drives the backlight **820** so that light of constant intensity is emitted from the backlight **820** in the driving of the liquid crystal display device **800**.

Table 5 shows the luminance ratios of the red sub-pixel R, the green sub-pixel G, the blue sub-pixels B, and the yellow sub-pixel Ye in the liquid crystal display device **800** in the comparative example 2. For example, the luminance ratio of the red sub-pixel R shows the ratio of luminance in which the red sub-pixel R exhibits the maximum transmittance and the other sub-pixels (i.e., the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye) exhibit the minimum transmittance with respect to the luminance when white (W) is displayed. Similarly, the luminance ratio of each of the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye indicates the ratio of luminance in which the corresponding sub-pixel exhibits the maximum transmittance and the other sub-pixels exhibit the minimum transmittance with respect to the luminance when white (W) is displayed.

TABLE 5

	Luminance Ratio
R	10.7%
G	33.8%
B	11.8%
Ye	43.7%
W	100%

FIG. **12** shows luminance levels r, g and b of the input video signal, relative intensities br, bg, and bb of the backlight **820**, transmittance levels pr, pg, and pb of a liquid crystal data, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **810**, in the liquid crystal display device **800**.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0. The luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), and the grayscale levels (r, g, b) are (0, 128, 0) in the 255 grayscale notation. In the liquid crystal display device **800**, the backlight **820** emits light of constant intensity irrespective of the color indicated in the input video signal. Herein the relative intensities (br, bg, bb) are indicated by (1, 1, 1).

In the liquid crystal display device **800**, the transmittance levels (the grayscale levels) pr, pg, and pb of the liquid crystal data signal are the same as the luminance levels (the grayscale levels) r, g, and b of the input video signal. Accordingly, as described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the transmittance levels pr, pg, and pb of the liquid crystal data signal also satisfy the relationship of pg>pr=pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 0.216, 0), and the grayscale levels (pr, pg, pb) are (0, 128, 0) in the 255 grayscale notation.

In the liquid crystal display device **800**, multi-primary color conversion is performed. The relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **810** are (0, 0.216, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_Y) are (0, 128, 0, 0) in the 255 grayscale notation.

As is understood from the comparison between FIG. **8**, and FIG. **10** and FIG. **12**, in the liquid crystal display devices **700** and **800**, the light of constant intensity emitted from the backlights **720** and **820** is modulated in the liquid crystal panels **710** and **810**. On the other hand, in the liquid crystal display device **100**, the light modulation is performed in the backlight **20**. The liquid crystal panel **10** makes the relative transmittance of a sub-pixel related to the light from the backlight **20** to be the maximum value, and makes the relative transmittances of sub-pixels not related to the light from the backlight **20** to be the minimum value. Thus, in the liquid crystal display devices **700** and **800**, light of constant intensity is emitted from the backlights **720** and **820**. In the liquid crystal display device **100**, the light sources **22**R and **22**B are turned off in accordance with the input video signal, and additionally the intensity of the light source **22**G can be reduced. Accordingly, the power consumption of the backlight **20** can be reduced.

In the above description, the color indicated in the input video signal is green. However, even if the color indicated in the input video signal is an arbitrary color, the power consumption can be reduced and the contrast ratio can be increased, for the same reasons.

In the liquid crystal display device **700** in the comparative example 1, display is performed with three primary colors. In the liquid crystal display device **100** in this embodiment, and in the liquid crystal display device **800** in the comparative example 2, display is performed with four primary colors. Accordingly, display can be performed in wide color reproduction range. However, in the liquid crystal display device **800** in the comparative example 2, color of high brightness cannot be displayed in some cases.

Hereinafter, normalized luminance in the case where an input video signal indicating a specific color is input will be described in the liquid crystal display device **700** in the comparative example 1, in the liquid crystal display device **800** in the comparative example 2, and in the liquid crystal display device **100** in this embodiment.

First, normalized luminance in the case where the input video signal indicates yellow of high brightness is compared among the liquid crystal display device **700** in the comparative example 1, the liquid crystal display device **800** in the comparative example 2, and the liquid crystal display device **100** in this embodiment. The configurations of the liquid crystal display devices **700** and **800** in the comparative examples 1 and 2 are described above with reference to FIG. **9** and FIG. **11**, so that overlapping descriptions are omitted for avoiding verbose descriptions.

In the case where the input video signal indicates yellow of high brightness, for example, in the case where the grayscale levels (r, g, b) are (255, 255, 0), the liquid crystal display device **700** in the comparative example 1 makes the liquid crystal layers LC_R and LC_G in the liquid crystal panel **710** to have the maximum transmittances. In this case, the normalized luminance is 0.812 (=0.246+0.566).

In the case where the input video signal indicates yellow of high brightness, for example, in the case where the grayscale levels (r, g, b) of the input video signal are (255, 255, 0), the liquid crystal display device **800** in the comparative example 2 makes the liquid crystal layers LC_R, LC_G and LC_Y in the liquid crystal panel **810** to have the maximum transmittances. In this case, the normalized luminance is 0.882 (=0.107+0.338+0.437). In this way, the liquid crystal display device **800** in the comparative example 2 can display yellow of high brightness similarly to the liquid crystal display device **700** in the comparative example 1.

Similarly, in the case where yellow of high brightness is displayed, for example, in the case where the grayscale levels (r, g, b) of the input video signal are (255, 255, 0), the relative intensities (br, bg, bb) of the backlight **20** are (1, 1, 0), and the grayscale levels (p_R, p_G, p_B p_Y) of the liquid crystal panel **10** are (255, 255, 0, 255) in the 255 grayscale notation, in the liquid crystal display device **100** in this embodiment. In this case, the normalized luminance is 0.882. In this way, the liquid crystal display device **100** can display yellow of high brightness similarly to the liquid crystal display devices **700** and **800** in the comparative examples 1 and 2.

As described above, the liquid crystal display device **800** in the comparative example 2 can display yellow of high brightness similarly to the liquid crystal display device **700** in the comparative example 1. However, the liquid crystal display device **800** in the comparative example 2 cannot display other colors (chromatic colors) with high brightness.

Hereinafter with reference to FIG. **13**, the liquid crystal display device **700** in the comparative example 1 will be described. FIG. **13** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb, of the backlight **720**, and relative transmittances pr, pg, and pb of the liquid crystal panel **710** in the liquid crystal display device **700**.

Herein the input video signal indicates orange. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0. The luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), and the grayscale levels (r, g, b) are (255, 128, 0). In the liquid crystal display device **700**, irrespective of the color indicated by the input video signal, the backlight **720** emits light of constant intensity. Herein the relative intensities (br, bg, bb) of the backlight **720** are indicated by (1, 1, 1).

In the liquid crystal display device **700**, the transmittance levels (the grayscale levels) pr, pg, and pb of the liquid crystal data signal are equal to the luminance levels (the grayscale levels) r, g, b of the input video signal. Accordingly, as described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0, the transmittance levels pr, pg, and pb of the liquid crystal data signal also satisfy the relationship of pr>pg>pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 0.216, 0).

In the liquid crystal display device **700**, voltages corresponding to the transmittance levels (pr, pg, pb) are applied across the liquid crystal layers. As described above, in the liquid crystal display device **700**, the red, green, and blue sub-pixels R, G, and B exhibit the luminance corresponding to the luminance levels r, g, and b.

In the liquid crystal display device **700** in the comparative example 1, the grayscale levels (r, g, b) of the red, green, and blue sub-pixels are (255, 128, 0). In this case, the normalized luminance is 0.368 ($=0.246\times(255/255)^{2.2}+0.566\times(128/255)^{2.2}+0.188\times(0/255)^{2.2}$). Table 6 shows the grayscale levels of the respective sub-pixels in the liquid crystal panel **710** and the normalized luminance.

TABLE 6

	R	G	B	Normalized luminance
Grayscale level in Comparative Example 1	255	128	0	0.368

Next, with reference to FIG. **14**, the liquid crystal display device **800** in the comparative example 2 will be described. FIG. **14** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **820**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **810** in the liquid crystal display device **800**.

Also herein the input video signal indicates orange. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0. The luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), and the grayscale levels (r, g, b) are (255, 128, 0). In the liquid crystal display device **800**, irrespective of the color indicated in the input video signal, the backlight **820** emits light of constant intensity. Herein the relative intensities (br, bg, bb) of the backlight **820** are indicated by (1, 1, 1).

In the liquid crystal display device **800**, the transmittance levels (the grayscale levels) pr, pg, and pb of the liquid crystal data signal are equal to the luminance levels (the grayscale levels) r, g, b of the input video signal. The transmittance levels pr, pg, and pb of the liquid crystal data signal also satisfy the relationship of pr>pg>pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 0.216, 0).

In the liquid crystal display device **800**, multi-primary color conversion is performed. The relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **810** are (1, 0, 0, 0.276), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (255, 0, 0, 142) in the 255 grayscale notation. The normalized luminance in the liquid crystal display device **800** is 0.226 ($=0.107\times(255/255)^{2.2}+0.338\times(0/255)^{2.2}+0.118\times(0/255)^{2.2}+0.437\times(142/255)^{2.2}$). Table 7 shows the grayscale levels of the respective sub-pixels in the liquid crystal panel **810** and the normalized luminance in the liquid crystal display device **800**. In Table 7, the values of the liquid crystal display device **700** in the comparative example 1 are also shown for reference.

TABLE 7

	R	G	B	Ye	Normalized luminance
Grayscale level in Comparative Example 1	255	128	0	—	0.368
Grayscale level in Comparative Example 2	255	0	0	142	0.226

As shown in the table, the normalized luminance of the liquid crystal display device **800** in the comparative example 2 is low, so that orange of high brightness cannot be displayed. Although the detailed description is omitted, the liquid crystal display device **800** in the comparative example 2 cannot display yellowish green of high brightness for the same reason. Thus, in the liquid crystal display device **800** in the comparative example 2, chromatic colors other than yellow cannot be displayed with high brightness. It is considered that the reason why is that in the case where the size of a pixel P of the liquid crystal display device **800** is equal to that of a pixel P of the liquid crystal display device **700**, the area of the red sub-pixel R, the green sub-pixel G, and the blue sub-pixel B in the liquid crystal panel **810** is smaller than the area of the red sub-pixel R, the green sub-pixel G, and the blue sub-pixel B in the liquid crystal panel **710**.

FIG. **15** shows the normalized luminance of the liquid crystal display devices **700** and **800** in the case where the color phase of color indicated in the input video signal is varied in the range from red to green via yellow.

As described above, in the case where the input video signal indicates yellow of high brightness, the luminance of the liquid crystal display device **800** is the same as that of the liquid crystal display device **700**. On the contrary, in the case where the input video signal indicates red of high brightness, the luminance of the liquid crystal display device **800** is lower than that of the liquid crystal display device **700**. In the case where the input video signal indicates green of high brightness, the luminance of the liquid crystal display device **800** is lower than that of the liquid crystal display device **700**.

As is understood from FIG. **15**, in the case where the intermediate color between yellow and red (i.e. orange) is displayed with high brightness, the luminance of the liquid crystal display device **800** is lower than that of the liquid crystal display device **700**. Similarly, in the case where the intermediate color between yellow and green (i.e. yellowish green) is displayed with high brightness, the luminance of the liquid crystal display device **800** is lower than that of the liquid crystal display device **700**. As described above, the liquid crystal display device **800** in the comparative example 2 cannot display specific chromatic colors with the same brightness as that of the liquid crystal display device **700** which performs display with three primary colors.

On the contrary, the liquid crystal display device **100** in this embodiment can perform display in a wider color reproduction range than that of the liquid crystal display device **700** in the comparative example 1. In addition, the liquid crystal display device **100** in this embodiment can display colors of higher brightness as compared with the liquid crystal display device **800** in the comparative example 2.

Hereinafter, with reference to FIG. **16**, the relative transmittance of the liquid crystal panel **10** and the relative intensity of the backlight **20** in the liquid crystal display device **100** will be described. FIG. **16** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100**.

Also herein the input video signal indicates orange. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0. The luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), and the grayscale levels (r, g, b) are (255, 128, 0) in the 255 grayscale notation.

The magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is the same as the magnitude correlation among the grayscale levels r, g, and b of the input video signal. Accordingly, the relationship of r>g>b=0 is satisfied, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of br>bg>bb=0. For example, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b. Accordingly, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the relative intensities (br, bg, bb) are (1, 0.216, 0). Table 8 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 8

Embodiment 1	br	bg	bb
Relative Intensity of Backlight	1	0.216	0

In the liquid crystal display device **100**, the transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, b of the input video signal. In the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0, the grayscale levels pr and pg have the maximum value, and the grayscale level pb has the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (255, 255, 0) in the 255 grayscale notation.

Thereafter, by the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (1, 1, 0, 1), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (255, 255, 0, 255) in the 255 grayscale notation. Table 9 shows the grayscale levels of the liquid crystal panel **10**. The grayscale level of 255 of the liquid crystal panel corresponds to the relative transmittance of 1, and the grayscale level of 0 of the liquid crystal panel corresponds to the relative transmittance of 0.

TABLE 9

Embodiment 1	Red sub-pixel	Green sub-pixel	Blue sub-pixel	Yellow sub-pixel
Grayscale level of Liquid crystal panel	255	255	0	255

Thus, in the case where the liquid crystal panel **10** and the backlight **20** are driven, the normalized luminance of the liquid crystal display device is 0.348.

As is understood from the comparison between FIG. **14** and FIG. **16**, in the liquid crystal display device **800**, the light of constant intensity emitted from the backlight **820** is modulated in the liquid crystal panel **810**. On the other hand, in the liquid crystal display device **100**, the light sources **22**R and **22**G related to orange to be displayed are turned on, and the light source **22**B which is not related to orange to be displayed is turned off. In addition, the intensity of the light source **22**G is made to be lower than the maximum value. Since the backlight **20** performs such light modulation, the power consumption of the backlight **20** can be reduced. In the liquid crystal display device **800**, the light emitted from the backlight **820** with constant intensity is modulated in the liquid crystal panel **810**. On the other hand, in the liquid crystal display device **100**, the light modulation is performed in the backlight **20**, and in addition, the liquid crystal panel **10** makes the relative transmittance of a sub-pixel related to the light from the backlight **20** to be the maximum value, and the relative transmittance of a sub-pixel not related to the light from the backlight **20** to be the minimum value. Accordingly, the contrast ratio can be increased.

As described above, the normalized luminance of the liquid crystal display device **800** is 0.226, but the normalized luminance of the liquid crystal display device **100** in this embodiment is 0.348. This is because the grayscale levels p_R, p_G, and p_Y of the liquid crystal panel **10** are the maximum value, and the light of the light sources **22**R and **22**G which are turned on is efficiently transmitted through the liquid crystal panel **10** in the liquid crystal display device **100**. Accordingly, the liquid crystal display device **100** can display orange of high brightness.

In the above description, for example, in the case where the grayscale level r of the input video signal is the minimum value, the relative intensity br of the backlight **20** exhibits the minimum value, and the grayscale level p_R of the liquid crystal panel **10** exhibits the minimum value. However, the present invention is not limited to this. Alternatively, in the case where the grayscale level r of the input video signal is the minimum value, the grayscale level p_R may be an arbitrary value, and the relative intensity br of the backlight **20** may exhibit the minimum value. Alternatively, in the case where the grayscale level r of the input video signal is the minimum value, the relative intensity br of the backlight **20** may be an arbitrary value, and the grayscale level p_R may exhibit the minimum value.

Strictly speaking, even in the case where the relative intensity br of the backlight **20** is the minimum value (i.e. even in the case where the light source **22**R of the backlight **20** is turned off), part of light emitted from another light source may sometimes be transmitted through the red sub-pixel R. Similarly, even in the case where the grayscale level p_R in the liquid crystal panel **10** is the minimum value, the light emitted from the light source **22**R of the backlight **20** may sometimes be transmitted through the liquid crystal panel **10**. For this reason, in the case where the grayscale level r of the input video signal is the minimum value, it is preferred that the grayscale level p_R may be the minimum value. Accordingly, high contrast ratio can be realized. As for the grayscale levels g and b of the input video signal, the same may be described.

In the above description, the color indicated in the input video signal is orange, but the color indicated in the input video signal may be any other color.

FIG. **17** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100** in the case where the input video signal indicates yellowish green. Herein the input video signal indicates yellowish green, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r>b=0, the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0), and the grayscale levels (r, g, b) are (128, 255, 0), for example.

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. In the case where the luminance levels r, g, and b satisfy the relationship of g>r>b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of bg>br>bb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0), the relative intensities (br, bg, bb) are (0.216, 1, 0).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r>b=0, the grayscale levels pr and pg corresponding to the luminance levels r and g have the maximum values, and the grayscale level pb corresponding to the luminance level b has the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (255, 255, 0) in the 255 grayscale notation. By the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (1, 1, 0, 1) and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (255, 255, 0, 255) in the 255 grayscale notation.

FIG. **18** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100** in the case where the input video signal indicates light green. Herein the input video signal indicates light green, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b>0, the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0.216), and the grayscale levels (r, g, b) are (128, 255, 128), for example.

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. In the case where the luminance levels r, g, and b satisfy the relationship of g>r=b>0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of bg>br=bb>0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0.216), the relative intensities (br, bg, bb) are (0.216, 1, 0.216).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b>0, the grayscale levels pr, pg, and pb corresponding to the luminance levels r, g and b have the maximum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0.216, 1, 0.216), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 1, 1), and the grayscale levels (pr, pg, pb) are represented by (255, 255, 255) in the 255 grayscale notation. By the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (1, 1, 1, 1), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (255, 255, 255, 255).

With reference to FIG. **19**, the configuration of the active drive processing portion **32** will be described. FIG. **19** is a schematic diagram of the active drive processing portion **32**. The active drive processing portion **32** includes a gamma converting portion **32***a*, a light source intensity determining portion **32***b*, a backlight intensity determining portion **32***c*, a panel transmission determining portion **32***d*, and a gamma converting portion **32***e*.

The gamma converting portion **32***a* performs inverse gamma correction for the grayscale levels r, g, and b of the input video signal. Generally, the input video signal is subjected to the gamma correction processing, and the input video signal indicates the grayscale levels r, g, and b which are nonlinear with respect to the luminance. In the gamma converting portion **32***a*, the inverse gamma correction processing is performed for the input video signal, so that the grayscale levels r, g, and b are converted so as to be linear with respect to the luminance of the respective primary colors, thereby obtaining luminance levels r, g, and b.

The light source intensity determining portion **32***b* determines the relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B of the backlight **20** based on the luminance levels r, g, and b. The relative intensities sr, sg, and sb may be set based on the sampling results of the luminance levels r, g, and b of the input video signal. Alternatively, the relative intensities sr, sg, and sb may be determined based on the respective maximum value of each of the luminance levels r, g, and b of the input video signal. Alternatively, the relative intensities sr, sg, and sb may be determined based on the mean value of each of the luminance levels r, g, and b of the input video signal. Alternatively, the relative intensities sr, sg, and sb may be determined based on the weighted average of the mean value and the maximum value of each of the luminance levels r, g, and b of the input video signal. The maximum value, the mean value, and the weighted average of them are described in International Publication No. WO 2009/054223, for example. Thereafter, the light source intensity determining portion **32***b* outputs a light source signal indicating the relative intensities sr, sg, and sb to the backlight driving circuit **38**.

The backlight intensity determining portion **32***c* calculates the relative intensities br, bg, and bb from the backlight **20** based on the relative intensities sr, sg, and sb. The relative intensities br, bg, and bb are obtained by light diffusion filter and linear interpolation.

The panel transmission determining portion **32***d* determines the transmission levels pr, pg, and pb of red, green, and blue of the three primary color liquid crystal display device from the relationship between the luminance levels r, g, and b of the input video signal and the relative intensities br, bg, and bb of the backlight **20**. The transmittance levels pr, pg, and pb correspond to the relative transmittances of the red, green, and blue liquid crystal layers LC_R, LC_G, and LC_B in the three primary color liquid crystal display device, and the transmittance levels pr, pg, and pb have linear relationships with respect to the luminance (the intensities of emitted light). In the above description, all of the pixels exhibit the same color in the input video signal and the intensities of light emitted from the backlight **20** are the same for pixels p. However, in the case where the pixels exhibit different colors in the input video signal, and/or in the case where the intensities of light emitted from the backlight **20** are different for the pixels P, the transmittance levels pr, pg, and pb are different depending on the respective pixel P.

Thereafter, the gamma converting portion **32***e* converts the transmittance levels pr, pg, and pb to grayscale levels pr, pg, and pb. Specifically, the gamma converting portion **32***e* performs gamma correction processing for the transmission levels pr, pg, and pb, thereby determining the grayscale levels pr, pg, and pb having nonlinear relationship with respect to the luminance.

(Embodiment 2)

Hereinafter a liquid crystal display device in a second embodiment of the present invention will be described. FIG. **20**(*a*) shows a schematic diagram of the liquid crystal display device **100**A in this embodiment. The liquid crystal display device **100**A is provided with a liquid crystal panel **10** and a backlight **20**.

FIG. **20**(*b*) shows a schematic diagram of a pixel P in the liquid crystal panel **10**. Also herein, the pixel P includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a yellow sub-pixel Ye. As described above with reference to FIG. **1**(*d*) and FIG. **1**(*e*), the backlight **20** includes a light source unit **22** having light sources **22**R, **22**G, and **22**B.

FIG. **21** shows a schematic diagram of the liquid crystal display device **100**A provided with a control circuit **30**A. The control circuit **30**A controls the liquid crystal panel **10** and the backlight **20** based on an input video signal. The control circuit **30**A includes an active drive processing portion **32**, a multi-primary color converting portion **34**A, a panel driving circuit **36**, and a backlight driving circuit **38**. The control circuit **30**A has the same configuration as that of the control circuit **30** described above with reference to FIG. **7**, so that overlapping descriptions are omitted in order to avoid verbose descriptions.

The active drive processing circuit **32** generates a light source signal and a liquid crystal data signal based on the input video signal. The light source signal indicates relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B. The relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B are set based on the luminance levels r, g, and b of the input video signal. The backlight driving circuit **38** drives the light sources **22**R, **22**G, and **22**B of the backlight **20** based on the light source signal. At this time, light of relative intensities br, bg, and bb is emitted from the backlight **20**.

The active drive processing portion **32** generates a backlight signal from the light source signal. The backlight signal indicates the relative intensities br, bg, and bb of the backlight **20**. In the active drive processing portion **32**, the relative intensities br, bg, and bb of the backlight **20** are obtained from the relative intensities sr, sg, and sb. As described above, the relative intensities br, bg, and bb are set depending on the luminance levels r, g, and b of the input video signal. For example, the magnitude correlation among the relative intensities br, bg, and bb may be the same as the magnitude correlation among the luminance levels r, g, and b, or the relative intensities br, bg, and bb may be substantially equal to the luminance levels r, g, and b.

Alternatively, the relative intensities br, bg, and bb may be determined in any other conditions based on the luminance levels r, g, and b. The relative intensities br, bg, and bb of the backlight **20** may be higher than the luminance levels r, g, and b in accordance with the input video signal. As described above, in the case where all of the pixels exhibit the same color in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may be equal to the luminance levels r, g, and b of the input video signal. On the other hand, in the case where the pixels exhibit different colors in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may sometimes be higher than the luminance levels r, g, and b of the input video signal. Specifically, in the input video signal, in the case where grayscale levels of red are different among a plurality of pixels corresponding to a certain light source unit **22**, the relative intensity br of the backlight **20** is set in accordance with the maximum value of the grayscale level r, and the relative intensity br is higher than the grayscale level r of the other pixels. Similarly, in the input video signal, grayscale levels of green and blue are different among a plurality of pixels corresponding to the light source unit **22**, the relative intensities bg and bb of the backlight **20** are set in accordance with the maximum value of the grayscale levels g and b, and the relative intensities bg and bb are higher than the grayscale levels bg and bb of the other pixels.

Alternatively, even in the case where all of the pixels in the input video signal exhibit the same color, if the relative intensities br, bg, and bb of the backlight **20** are made to be equal to the luminance levels r, g, and b of the input video signal, the display characteristics such as color shift or viewing angle characteristic may sometimes be deteriorated. In such a case, even if all of the pixels exhibit the same color in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may be made to be higher than the luminance levels r, g, and b of the input video signal.

As described above, the relative intensities br, bg, and bb are determined based on the luminance levels r, g, and b. For example, a relative intensity corresponding to the lower one of the luminance levels r and g in the relative intensities br and bg is set to be a higher value than the lower luminance level. For example, in the case where the lower value is α and the higher value is β in the luminance levels r and g, a relative intensity corresponding to the lower one of the luminance levels r and g in the relative intensities br and bg may be set to be not lower than α and not higher than β. For example, in the case where the luminance levels (r, g, b) are (0, 1, 0), the relative intensity bg is 1, the relative intensity bb is 0, and the relative intensity br is set to be a value not lower than 0 and not higher than 1.

The multi-primary color converting portion **34**A converts the grayscale levels pr, pg, and pb of the liquid crystal data signal to the red, green, blue and yellow grayscale levels p_1, p_2, p_3, and p_4. As described above, the color phase of color indicated by the grayscale levels pr, pg, and pb before the conversion is substantially the same as that of color indicated by the grayscale levels p_1, p_2, p_3, and p_4 after the conversion.

Thereafter, the multi-primary color converting portion **34**A generates a panel signal which indicates the grayscale levels p_1, p_2, p_3, and p_4 as grayscale levels p_R, p_G, p_B, and p_Y. Alternatively, the multi-primary color converting portion **34**A sets the grayscale levels p_1, p_2, and p_3 as grayscale levels p_R, p_G, and p_B, respectively, and a level p_4' which is higher than the grayscale level p_4 may be set as the grayscale level p_Y.

For example, the multi-primary color converting portion **34**A may set the grayscale level p_4' based on the backlight signal. As described later, as the grayscale level **p4'** is increased, the chromaticity is sifted together with the increase of the normalized luminance. Thus, it is preferred that the grayscale level p_4' may be set to such a degree that the shift of the chromaticity is not too much.

For example, the multi-primary color converting portion **34**A sets the grayscale level p_4' based on the relative intensities br and bg of the backlight **20**. The grayscale level p_4' may be set to be a constant value based on the relative intensities br and bg of the backlight **20**, or alternatively, may be continuously changed in accordance with the relative intensities br and bg. Thus, the multi-primary color converting portion **34**A may generate a panel signal based on not only the liquid crystal data signal but also the backlight signal. The panel driving circuit **36** drives the liquid crystal panel **10** based on the panel signal indicating the grayscale levels p_R, p_G, p_B, and p_Y.

Hereinafter the liquid crystal display device **100**A in the case where the input video signal indicates green will be described. For example, the grayscale levels (r, g, b) are (0, 255, 0) in the 255 grayscale notation. Herein the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b. The multi-primary color converting portion **34**A generates a panel signal based on not only the liquid crystal data signal but also the backlight signal. In this case, the relative intensities (br, bg, and bb) of the backlight **20** are (0, 1, 0).

As the result of the conversion of the pr, pg, and pb by the multi-primary color converting portion **34**A, the grayscale levels (p_1, p_2, p_3, p_4) of the red, green, blue, and yellow sub-pixels are (0, 255, 0, 0). The color phase of color indicated by the grayscale levels pr, pg, and pb is substantially the same as that of color indicated by the grayscale levels p_1, p_2, p_3, and p_4.

Thereafter the multi-primary color converting portion **34**A sets the grayscale level p_4' based on the relative intensities br, bg, and bb of the backlight **20**. Herein the difference between the relative intensities br and bg is large, so that the multi-primary color converting portion **34**A sets the grayscale level p_4' which is higher than the grayscale level p_4 as the grayscale level p_Y. Accordingly, the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, p_4') in the 255 grayscale notation. Herein the grayscale level p_4' is $0<p_4'\leq 255$, and the relative transmittance p_4' is $0<p_4'\leq 1$. Thus, in the case where the input video signal indicates green, in the liquid crystal display device **100**A, the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, p_4'), and the grayscale levels (p_R, p_G, p_B, p_Y) are (0, 255, 0, p_4') in the 255 grayscale notation.

In the liquid crystal display device **100**A, in the case where the light source **22**G of the backlight **20** is turned on, and the light sources **22**R and **22**B are turned off, the light from the backlight **20** is transmitted through not only the green sub-pixel G but also the yellow sub-pixel Ye. Accordingly, the normalized luminance can be efficiently increased.

Hereinafter the normalized luminance of the liquid crystal display device **100**A will be described with reference to FIG. **22**.

FIG. **22**(*a*) shows an emission spectrum of the backlight **20**. Herein the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), so that the light source **22**G is in the on state. The emission spectrum has the peak wavelength of about 520 nm. FIG. **22**(*a*) is the same as FIG. **5**(*a*).

FIG. **22**(*b*) shows a transmission spectrum of the liquid crystal panel **10**. Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 0, 0, 255), so that the light is transmitted through the yellow sub-pixel Ye. Accordingly, the liquid crystal panel **10** mainly transmits light having wavelengths of 500 nm or more.

FIG. **22**(*c*) shows an emission spectrum of the liquid crystal display device **100**A in the case where the light of the spectrum shown in FIG. **22**(*a*) is emitted from the backlight **20** and the light is transmitted through the liquid crystal panel with the spectrum shown in FIG. **22**(*b*). Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 0, 0, 255), and the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). In such a case, the intensity of light emitted from the yellow sub-pixel Ye is mainly expressed by the product of the intensity of light from the light source **22**G in the backlight **20** and the transmittance of the yellow sub-pixel Ye. The emission spectrum also has the peak wavelength of about 520 nm.

FIG. **22**(*d*) shows an emission spectrum of the liquid crystal display device **100**A in the case where the light of the spectrum shown in FIG. **22**(*a*) is emitted from the backlight **20**, and the light is transmitted through the liquid crystal panel **10** with the spectra shown in both of FIG. **5**(*b*) and FIG. **22**(*b*). Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 255), and the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). In such a case, the intensity of light emitted from the liquid crystal display device **100**A is the sum of the intensity of light emitted from the light source **22**G and transmitted through the green sub-pixel G and the intensity of light transmitted through the yellow sub-pixel Ye, so that green with high brightness can be displayed. Herein the light source **22**G is turned on, but the light source **22**R is turned off, so that if the light is transmitted through not only the green sub-pixel G but also the yellow sub-pixel Ye in the liquid crystal panel **10**, the color phase of color displayed by the liquid crystal display device **100**A are hardly varied.

Herein the advantages of the liquid crystal display device **100**A will be described as compared with the liquid crystal display devices **700** and **800** in the comparative examples 1 and 2. First, the liquid crystal display device **700** in the comparative example 1 will be described. The configuration of the liquid crystal display device **700** in the comparative example 1 is described above with reference to FIG. **9**, so that overlapping descriptions are omitted for avoiding verbose descriptions.

Herein the color indicated in the input video signal is green, and the grayscale levels (r, g, b) are (0, 255, 0) in the 255 grayscale notation. In the liquid crystal display device **700** in the comparative example 1, light of constant intensity is emitted from the backlight **720**. Herein the relative intensities (br, bg, bb) of the backlight **720** are represented as (1, 1, 1).

The grayscale levels (pr, pg, pb) of the red, green, and blue sub-pixels in the liquid crystal panel **710** are equal to the grayscale levels (r, g, b) of the input video signal, i.e., (0, 255, 0). In this case, the normalized luminance in the liquid crystal display device **700** is 0.566 ($=0.246\times(0/255)^{2.2}+0.566\times(255/255)^{2.2}+0.188\times(0/255)^{2.2}$). Table 10 shows the grayscale levels of respective sub-pixels in the liquid crystal panel **710**.

TABLE 10

	R	G	B	Ye	Normalized Luminance
Grayscale level of Comparative example 1	0	255	0	—	0.566

Next, the liquid crystal display device **800** in the comparative example 2 will be described. The configuration of the liquid crystal display device **800** in the comparative example 2 is described above with reference to FIG. **11**, so that overlapping descriptions are omitted for avoiding verbose descriptions.

Herein the color indicated in the input video signal is green, and the grayscale levels (r, g, b) are (0, 255, 0) in the 255 grayscale notation. In the liquid crystal display device **800** in the comparative example 2, light of constant intensity is emitted from the backlight **820**. Herein the relative intensities (br, bg, bb) of the backlight **820** are indicated by (1, 1, 1).

The grayscale levels (pr, pg, pb) of the liquid crystal data signal are equal to the grayscale levels (r, g, b) of the input video signal, i.e. (0, 255, 0). In the liquid crystal display device **800** in the comparative example 2, multi-primary color conversion is performed. The grayscale levels (p_R, p_G, p_B, p_Y) are (0, 255, 0, 0) in the 255 grayscale notation. In this case, the normalized luminance in the liquid crystal display device **800** is 0.338 ($=0.107\times(0/255)^{2.2}+0.338\times(255/255)^{2.2}+0.118\times(0/255)^{2.2}+0.44\times(0/255)^{2.2}$). Table 11 shows grayscale levels of respective sub-pixels in the liquid crystal panel **810**. Table 11 also shows the values of the liquid crystal display device **700** in the comparative example 1 for reference.

TABLE 11

	R	G	B	Ye	Normalized luminance
Grayscale level in Comparative example 1	0	255	0	—	0.566
Grayscale level in Comparative example 2	0	255	0	0	0.338

Thus, the normalized luminance of the liquid crystal display device **800** in the comparative example 2 is low, so that the liquid crystal display device **800** cannot display green of high brightness.

In the above-described liquid crystal display device **100**, in the case where the input video signal indicates green, the light source **22**G of the backlight **20** is turned on, and the light is transmitted through the green sub-pixel G. For example, as described above with reference to FIG. **5**, in the case where the grayscale levels (r, g, b) of the input video signal are (0, 255, 0), the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (0 255, 0, 0) in the 255 grayscale notation. In this case, the light of the spectrum shown in FIG. **5**(*c*) is emitted, but high brightness cannot be obtained by the light only in some cases.

On the contrary, the liquid crystal display device **100**A in this embodiment can display green of high brightness. Hereinafter the normalized luminance of the liquid crystal display device **100**A will be described. Herein the color indicated in the input video signal is also green, the luminance levels (r, g, b) are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

Herein the relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. Table 12 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 12

Embodiment 2	br	bg	bb
Relative intensity of Backlight	0	1	0

As described above, herein the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, p_4'), and the grayscale levels (p_R, p_G, p_B, p_Y) are (0, 255, 0, p_4') in the 255 grayscale notation. Table 13 shows the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel Ye in the liquid crystal panel **10**.

TABLE 13

Embodiment 2	R	G	B	Ye
Grayscale level of Liquid crystal panel	0	255	0	p_4'

As described above, the relative transmittance p_4' is $0<p_4'\leq 1$, and the grayscale level p_4' is $0<p_4'\leq 255$. As the grayscale level p_4' increases, the improvement effect of the normalized luminance is increased. However, if the grayscale level p_4' is too high, the color phase of color displayed by the liquid crystal display device **100**A may sometimes be shifted largely. In addition, if the grayscale level p_4' is low, the shift of color is suppressed, but the improvement effect of the normalized luminance is reduced. For example, in the case where the grayscale level p_4' is the grayscale level of 222, the normalized luminance of the liquid crystal display device **100**A is 0.566 which is equal to that of the liquid crystal display device **700** in the comparative example 1. The grayscale level of 222 corresponds to the relative transmittance of 0.737.

FIG. **23** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of a liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100**A. Herein the input video signal also indicates green. For example, the luminance levels r, g, and b) of the input video signal satisfy the relationship of g>r=b 0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. In the case where the luminance levels r, g, and b satisfy the relationship of g>r=b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of bg>br=bb=0. Specifically, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), the relative intensities (br, bg, bb) are (0, 1, 0).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0, 1, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (0, 255, 0) in the 255 grayscale notation. In this case, as the result of the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, 0.737), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (0, 255, 0, 222) in the 255 grayscale notation.

In the above description, the color indicated in the input video signal is green. However the present invention is not limited to this. The color indicated in the input video signal may be red. For example, even in the case where the grayscale levels of the input video signal satisfy the relationship of r>g=b=0, the relative intensity br of the backlight **20** is made to be higher than the minimum value and not only the grayscale level p_R but also the grayscale level p_Y of the liquid crystal panel **10** are made to be higher than the minimum value, thereby displaying red of high brightness.

In the above description, the setting of the grayscale level p_4' is performed in the case where one of the relative intensities br and bg has the minimum value, and the other is higher than the minimum value. However, the present invention is not limited to this. For example, the setting of the grayscale level p_4' may be performed in the case where both of the relative intensities br and bg are higher than the minimum value.

In the above description, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b of the input video signal. However, the present invention is not limited to this. As for the relative intensities br, bg, and bb, one of the relative intensities br and bg corresponding to the lower one of the luminance levels r and g may be set to have a higher value than the lower luminance level.

Hereinafter with reference to FIG. **24**, the liquid crystal display device **100**A will be described. FIG. **24** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10** in the liquid crystal display device **100**A.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b. In the case where the luminance levels r, g, and b satisfy the relationship of g>r=b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationships of bg≥br≥0 and bg≥bb≥0. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0, 1, 0), the relative intensity bg is 1, the relative intensity bb is 0, and the relative intensity br is 0≤br≤1.

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0, 1, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (0, 255, 0) in the 255 grayscale notation.

Next, multi-primary color conversion is performed. Herein the relative transmittances (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 1, 0, 0.737), and the grayscale levels (p_R, p_G, p_B, p_Y) are represented by (0, 255, 0, 222) in the 255 grayscale notation. Herein similarly to the description with reference to FIG. **23**, the relative transmittances (p_R, p_G, p_B, p_Y) are (0, 1, 0, 0.737). However, since the relative intensity br of the backlight **20** is higher than the minimum value, the relative transmittance p_Y may be lower than 0.737. As described above, in the case where the input video signal indicates green, not only the relative intensity bg of the backlight **20** but also the relative intensity br may be higher than the minimum value.

In the above description, the color indicated in the input video signal is green. However, the present invention is not limited to this. The color indicated in the input video signal may be red. In this case, even when the grayscale levels of the input video signal satisfy the relationship of r>g=b=0, not only the relative intensity br of the backlight **20** but also the relative intensity bg may be higher than the minimum value, and the grayscale levels p_R and p_Y of the liquid crystal panel **10** may be higher than the minimum value.

In this way, in the case where the color indicated in the input video signal is green, not only the relative intensity bg of the backlight **20** but also the relative intensity br may be higher than the minimum value.

Hereinafter with reference to FIG. **25**, the variations of chromaticity and normalized luminance in accordance with the change of relative intensity br of the backlight **20** in the liquid crystal display device **100**A will be described. Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

FIG. **25**(*a*) shows the variation of chromaticity. In FIG. **25**(*a*), the axis of abscissa indicates chromaticity x and the axis of ordinate indicates chromaticity y. FIG. **25**(*b*) shows the variation of normalized luminance. In FIG. **25**(*b*), the axis of abscissa indicates the relative intensity br of the backlight **20**, and the axis of ordinate indicates the normalized luminance. Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 0), and the relative intensities bg and bb of the backlight **20** are 1 and 0, respectively.

As shown in FIG. **25**(*a*), the chromaticity x and the chromaticity y when the relative intensity br is 1 are substantially equal to those when the relative intensity br is 0. In the liquid crystal panel **10**, the green sub-pixel G transmits light and the other sub-pixels block out the light, so that even if the relative intensity br of the backlight **20** is increased, the light emitted from the liquid crystal panel **10** may hardly be affected. As is understood from FIG. **2** and FIG. **3**, the emission spectrum of the light source **22**R slightly overlaps the transmission spectrum of the green sub-pixel G. Due to the increase of the relative intensity br of the backlight **20**, the intensity of light of longer wavelengths in the light emitted from the liquid crystal panel **10** is slightly increased. Strictly speaking, as the relative intensity br increases, the chromaticity x and the chromaticity y are both shifted slightly.

As shown in FIG. **25**(*b*), the normalized luminance when the relative intensity br is 1 is substantially equal to that when the relative intensity br is 0. As described above, in the liquid crystal panel **10**, the green sub-pixel G transmits light, and the other sub-pixels block out the light, so that even if the relative intensity br of the backlight **20** increases, the light emitted from the liquid crystal panel **10** may hardly be affected.

As described above, in the liquid crystal panel **10**, in the case where not only the green sub-pixel G but also the yellow sub-pixel Ye transmit light, the chromaticity x, the chromaticity y, and the normalized luminance are varied in accordance with the increase of the relative intensity br, respectively.

With reference to FIG. **26**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity br of the backlight **20** in the liquid crystal display device **100**A will be described. FIG. **26**(*a*) shows the variation of chromaticity, and FIG. **26**(*b*) shows the variation of normalized luminance. For reference, in FIG. **26**(*b*), the normalized luminance when the grayscale level p_Y is zero is also shown.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 57), and the relative intensities bg and bb of the backlight **20** are 1 and 0, respectively.

As shown in FIG. **26**(*a*), by increasing the relative intensity br of the backlight **20**, the chromaticity x and the chromaticity y are relatively largely shifted. This is because since the green sub-pixel G transmits light and also the yellow sub-pixel Ye transmits light to some extent in the liquid crystal panel **10**, the intensity of light of longer wavelengths in the light emitted from the liquid crystal panel **10** is increased due to the increase of the relative intensity br.

As shown in FIG. **26**(*b*), the normalized luminance when the grayscale level p_Y is 57 is slightly larger than that when the grayscale level p_Y is 0. This is because, as described above, in the liquid crystal panel **10**, not only the green sub-pixel G but also the yellow sub-pixel Ye transmit light. It is noted that since the grayscale level p_Y in the liquid crystal panel **10** is relatively low, the influence on the normalized luminance is relatively small.

Next, with reference to FIG. **27**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity br of the backlight **20** in the liquid crystal display device **100**A will be described. FIG. **27**(*a*) shows the variation of chromaticity, and FIG. **27**(*b*) shows the variation of normalized luminance. For reference, in FIG. **27**(*b*), the normalized luminance when the grayscale level p_Y zero is also shown.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0). Herein the grayscale levels (p_R, p_G, p_B, p_Y) of the liquid crystal panel **10** are (0, 255, 0, 222), and the relative intensities bg and bb of the backlight **20** are 1 and 0, respectively.

As shown in FIG. **27**(*a*), by the increase of the relative intensity br of the backlight **20**, the chromaticity x and the chromaticity y are more largely shifted. This is because since not only the green sub-pixel G but also the yellow sub-pixel Ye transmit light in the liquid crystal panel **10**, the intensity of light of longer wavelengths in the light emitted from the liquid crystal panel **10** is largely increased, due to the increase of the relative intensity br.

As shown in FIG. **27**(*b*), the normalized luminance when the relative intensity br is 1 is larger than that when the relative intensity br is 0. This is because, in the liquid crystal panel **10**, the grayscale level p_Y is relatively high, and the influence on the normalized luminance in accordance with the increase of the relative intensity br is large. The normalized luminance when the grayscale level p_Y is 222 is larger than the normalized luminance when the grayscale level p_Y is 57.

As is understood from the comparison between FIG. **26** and FIG. **27**, in the case where the grayscale level p_Y is small, the variation of chromaticity is relatively small and the improvement effect of the normalized luminance is relatively small. On the other hand, in the case where the grayscale level p_Y is large, the improvement effect of the normalized luminance is relatively large, and the variation of chromaticity is also relatively large.

In the above description, irrespective of the change of the relative intensity br of the backlight **20**, the grayscale level p_Y in the liquid crystal panel **10** is constant. However the present invention is not limited to this. The grayscale level p_Y in the liquid crystal panel **10** may be varied in accordance with the change of the relative intensity br of the backlight **20**.

With reference to FIG. **28**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity br of the backlight **20** in the liquid crystal display device **100**A will be described. FIG. **28**(*a*) shows the variation of chromaticity, and FIG. **28**(*b*) shows the variation of normalized luminance. For reference, FIG. **28**(*b*) also shows respective normalized luminance when the grayscale level p_Y is 0, 57, and 222.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0). Herein the grayscale levels p_R, p_G, and p_B of the liquid crystal panel **10** are 0, 255, and 0, and the grayscale level p_Y is not lower than 57 and not higher than 222. The relative intensities bg and bb of the backlight **20** are 1 and 0, respectively.

Herein when the relative intensity br is 0, the grayscale level p_Y of the liquid crystal panel **10** is 222, and the grayscale level p_Y is decreased in accordance with the increase of the relative intensity br. When the relative intensity br is 1, the grayscale level p_Y of the liquid crystal panel **10** is 57.

As shown in FIG. **28**(*a*), by the increase of the relative intensity br of the backlight **20**, the chromaticity is slightly shifted, but the shift amount is relatively small. Herein the grayscale level p_Y is decreased in accordance with the increase of the relative intensity br, thereby reducing the shift of chromaticity.

As shown in FIG. **28**(*b*), in the case where the relative intensity br is 0, the improvement effect of the normalized luminance is large, but the improvement effect of the normalized luminance is reduced as the relative intensity br increases. Thus, in accordance with the increase of the relative intensity br, the grayscale level p_Y is reduced, so that it is possible to improve the normalized luminance and suppress the shift of chromaticity.

(Embodiment 3)

Hereinafter a second embodiment of a liquid crystal display device of the present invention will be described. FIG. **29**(*a*) shows a schematic diagram of a liquid crystal display device **200** in this embodiment. The liquid crystal display device **200** is provided with a liquid crystal panel **10**A and a backlight **20**.

FIG. **29**(*b*) shows a schematic diagram of a pixel P in the liquid crystal panel **10**A. The pixel P in the liquid crystal panel **10**A includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a white sub-pixel W. In other words, the pixel P in the liquid crystal panel **10**A is different from the pixel P in the liquid crystal panel **10** shown in FIG. **1**(*b*) in that the pixel P in the liquid crystal panel **10**A has the white sub-pixel W instead of the yellow sub-pixel Ye.

FIG. **29**(*c*) shows a schematic sectional view of the liquid crystal panel **10**A. In the white sub-pixel W, a colorless and transparent (i.e. for transmitting white light) color filter **13**W is disposed. Hereinafter a liquid crystal layer LC of the white sub-pixel W is sometimes referred to as a liquid crystal layer LC_W.

The backlight **20** includes a light source unit **22** having light sources **22**R, **22**G, and **22**B, as described above with reference to FIG. **1**(*d*) and FIG. **1**(*e*).

As described above, in the liquid crystal panel **10**A, the pixel P has the red, green, blue, and white sub-pixels R, G, B, and W. In this specification, a grayscale level of white of the liquid crystal panel **10**A (white displayed only by the white sub-pixel W) is denoted by p_W. The grayscale level p_W corresponds to the transmittance of the liquid crystal layer LC_W of the white sub-pixel W. Specifically, across the liquid crystal layer LC_W of the white sub-pixel W, a voltage corresponding to the grayscale level p_W is applied, thereby changing the transmittance of the white sub-pixel W.

In the case where the liquid crystal panel **10**A is of a normally black type, when the minimum applied voltage (typically a voltage of zero) is applied across the liquid crystal layer LC_W, the transmittance exhibits the minimum value. When the maximum applied voltage is applied across the liquid crystal layer LC_W, the transmittance exhibits the maximum value. In the case where the applied voltage across the liquid crystal layer LC_W is low, the transmittance of the white sub-pixel W is low. In addition, when the applied voltage across the liquid crystal layer LC_W is high, the transmittance of the white sub-pixel W is high.

Thus, the grayscale level p_W of the liquid crystal panel **10**A corresponds to the transmittance of the white sub-pixel W in the liquid crystal panel **10**A. In the following description of this specification, a transmittance normalized in such a manner that the minimum value is zero (0), and the maximum value is 1 in the white sub-pixel W is represented as a relative transmittance p_W.

The light emitted from the white sub-pixel W is the light emitted from the light sources **22**R, **22**G, and **22**B in the backlight **20**, and transmitted through the liquid crystal layer LC_W and the color filter **13**W in the liquid crystal panel **10**A. Accordingly, the intensity of light emitted from the white sub-pixel W is mainly expressed by the product of the sum of the intensities of light of the light sources **22**R, **22**G, and **22**B in the backlight **20**, and the transmittance of the white sub-pixel W. The transmittance of the white sub-pixel W is mainly expressed by the product of the transmittance of the color filter **13**W and the transmittance of the liquid crystal layer LC_W.

Table 14 shows the luminance ratios of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the white sub-pixel W in the liquid crystal display device **200**. The luminance ratio of the white sub-pixel W (recited in a box of Ws in Table 14) is a ratio of the luminance when the white sub-pixel W exhibits the maximum transmittance and the other sub-pixels exhibit the minimum transmittance to the luminance when white (W) is displayed by the entire of the pixel P (i.e., the luminance when all of the sub-pixels exhibit the maximum transmittance).

TABLE 14

	Luminance ratio
R	11.8%
G	29.6%
B	9.6%
Ws	49.0%
W	100%

In the liquid crystal display device **200** in this embodiment, each pixel P in the liquid crystal panel **10**A includes four or more sub-pixels exhibiting colors which are different from each other, and each light source unit **22** includes light sources **22**R, **22**G, and **22**B. Accordingly, display can be performed in wide color reproduction range. In accordance with the colors to be displayed, the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_W in the liquid crystal panel **10**A are changed, and additionally the relative intensities of the light sources **22**R, **22**G, and **22**B of each light source unit **22** in the backlight **20** can be changed. Accordingly, it is possible to increase the contrast ratio and to reduce the power consumption.

Specifically, in the case where the liquid crystal display device **200** displays red, the light source **22**R is turned on, and the light sources **22**G and **22**B are turned off in the backlight **20**, and the red sub-pixel R transmits light, and the other sub-pixels block out the light in the liquid crystal panel **10**A. Similarly, in the case where the liquid crystal display device **200** displays green, the light source **22**G is turned on, and the light sources **22**R and **22**B are turned off, and the green sub-pixel G transmits light and the other sub-pixels block out the light in the liquid crystal panel **10**A. Similarly, in the case where the liquid crystal display device **200** displays blue, the light source **22**B is turned on, and the light sources **22**R and **22**G are turned off, and the blue sub-pixel B transmits light and the other sub-pixels block out the light in the liquid crystal panel **10**A. Thus, by controlling the turning on and off of the light sources **22**R, **22**G, and **22**B in accordance with the colors to be displayed on the liquid crystal display device **200**, the power consumption can be reduced. In addition, in accordance with the colors to be displayed on the liquid crystal display device **200**, the transmittances of the red, green, blue, and white sub-pixels R, G, B, and W are changed and additionally the intensities of light emitted from the light sources **22**R, **22**G, and **22**B are controlled, thereby realizing high contrast ratio.

For example, in the case where the liquid crystal display device **200** displays green, light of the light source **22**G is emitted from the backlight **20**, and the green sub-pixel G of the liquid crystal panel **10**A transmits the light. Herein the grayscale levels (r, g, b) of the input video signal are (0, 255, 0) in the 255 grayscale notation.

FIG. **30**(*a*) shows an emission spectrum of the backlight **20**. Herein the relative intensities (sr, sg, sb) of the light sources **22**R, **22**G, and **22**B are (0, 1, 0), the light source **22**G is turned on, and the emission spectrum has the peak wavelength of about 520 nm.

FIG. **30**(*b*) shows a transmission spectrum of the liquid crystal panel **10**A. Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 0), and light having the wavelengths of 480 nm to 580 nm are mainly transmitted through the green sub-pixel G.

FIG. **30**(*c*) shows an emission spectrum of the liquid crystal display device **200** in the case where the light of the spectrum shown in FIG. **30**(*a*) is emitted from the backlight **20** and the light of the spectrum shown in FIG. **30**(*b*) is transmitted in the liquid crystal panel **10**A. As described above, the intensity of light emitted from the green sub-pixel G is mainly expressed by the product of the intensity of light of the light source **22**G in the backlight **20** and the transmittance of the green sub-pixel G. The emission spectrum also has the peak wavelength of about 520 nm.

As described above, in the case where the grayscale levels (r, g, b) of the input video signal are (0, 255, 0), the light sources **22**R and **22**B of the backlight **20** are turned off, and the light source **22**G is turned on. The relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). Table 15 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 15

Embodiment 3	br	bg	bb
Relative intensity of Backlight	0	1	0

The grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 0) in the 255 grayscale notation. Table 16 shows the grayscale levels of the liquid crystal panel **10**A.

TABLE 16

Embodiment 3	Red sub-pixel	Green sub-pixel	Blue sub-pixel	White sub-pixel
Grayscale level of Liquid crystal panel	0	255	0	0

Thus, in the liquid crystal display device **200**, the grayscale levels (p_R, p_G, p_B, p_W) of the red, green, blue, and white sub-pixels R, G, B, and W in the liquid crystal panel **10**A are (0, 255, 0, 0), the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), and the normalized luminance of the liquid crystal display device **200** is 0.293. The luminance ratio of the green sub-pixel shown in Table 14 is 29.6% (0.296), and the luminance ratio is higher than the normalized luminance when green is displayed on the liquid crystal display device **200**. The luminance ratio of the green sub-pixel G is a value obtained by turning on not only the light source **22**G but also the light sources **22**R and **22**B. On the other hand, the normalized luminance is a value obtained by turning on the light source **22**G only and turning off the light sources **22**R and **22**B.

The control of the liquid crystal panel **10**A and the backlight **20** is performed in the following way, for example. Hereinafter, with reference to FIG. **31**, the liquid crystal display device **200** will be described. The liquid crystal display device **200** is provided with a control circuit **30** that controls the liquid crystal panel **10**A and the backlight **20**. The control circuit **30** generates a light source driving signal and a panel driving signal based on the input video signal.

The backlight **20** is driven based on the light source driving signal generated in the control circuit **30**. The light source driving signal indicates the relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B in the backlight **20**. By the light source driving signal, the light sources **22**R, **22**G, and **22**B emit light with the relative intensities sr, sg, and sb. In this case, light of the relative intensities br, bg, and bb is emitted from the backlight **20**.

The liquid crystal panel **10**A is driven based on the panel driving signal generated in the control circuit **30**. The panel driving signal indicates the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A. The grayscale levels p_R, p_G, p_B, and p_W correspond to the applied voltages of the liquid crystal layers LC_R, LC_G, LC_B, and LC_W of the red, green, blue, and white sub-pixels R, G, B, and W in the liquid crystal panel **10**A. Specifically, based on the panel driving signal, voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_W are applied across the liquid crystal layers LC_R, LC_G, LC_B, and LC_W, thereby changing the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_W. In this way in the liquid crystal display device **200**, the relative intensities br, bg, and bb of the backlight **20** are changed, and additionally, the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_W of the red, green, blue, and white sub-pixels R, G, B, and W are changed. Accordingly, the color display pixel P can display various colors.

FIG. **32** shows a specific configuration of the control circuit **30**. The control circuit **30** includes an active drive processing portion **32**, a multi-primary color converting portion **34**, a panel driving circuit **36**, and a backlight driving circuit **38**.

The active drive processing portion **32** generates a light source signal indicating the relative intensities sr, sg, and sb, and a liquid crystal data signal indicating the grayscale levels pr, pg, and pb based on the input video signal indicating the grayscale levels r, g, and b.

The multi-primary color converting portion **34** generates a panel signal from the liquid crystal data signal. The above-described liquid crystal panel **10**A performs display by using four primary colors, so that a panel signal indicating grayscale levels of four primary colors is generated. Specifically, the multi-primary color converting portion **34** converts the grayscale levels pr, pg, and pb of the liquid crystal data signal into red, green, blue, and white grayscale levels p_1, p_2, p_3, and p_4 of the panel signal. Herein the color phase of color represented by the grayscale levels pr, pg, and pb before the conversion is substantially the same as the color phase of color represented by the grayscale levels p_1, p_2, p_3, and p_4 after the conversion. Thereafter the multi-primary color converting portion **34** generates a panel signal indicating the grayscale levels p_1, p_1, p_3, and p_4 as the grayscale levels p_R, p_G, p_B, and p_W.

The panel driving circuit **36** generates a panel driving signal based on the panel signal, thereby driving the liquid crystal panel **10**A. Across the liquid crystal layers LC_R, LC_G, LC_B, and LC_W of the liquid crystal panel **10**A, voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_W are applied, and the red, green, blue, and white sub-pixels R, G, B, and W of the liquid crystal panel **10**A exhibit transmittances corresponding to the grayscale levels p_R, p_G, p_B, and p_W. The backlight driving circuit **38** generates a PB, light source driving signal based on the light source signal. The light sources **22**R, **22**G, and **22**B of the backlight **20** are driven by the light source driving signal.

The luminance level r of the input video signal is expressed by the product of the relative intensity br of the backlight **20** and the transmittance level pr of the liquid crystal data signal. In the case where the luminance level r of the input video signal is a median value, a plurality of combinations of the relative intensity br and the transmittance level br are considered. If the transmittance level pr of the liquid crystal data signal has the maximum value, the relative intensity br can be lowered. As a result, the power consumption of the light source **22**R can be reduced. Similarly, in the case where the luminance levels g and b of the input video signal are median values, if the transmittance levels pg and pb in the liquid crystal data signal have the maximum value, the relative intensities bg and bb can be lowered. As a result, the power consumption of the light sources **22**G and **22**B can be reduced.

In the liquid crystal display device **200**, it is preferred that the grayscale levels p_R, p_G, p_B, p_W of the liquid crystal panel **10**A and the relative intensities br, bg, and bb of the backlight **20** may be set in the following way based on the grayscale levels r, g, and b of the input video signal.

For example, in the case where the grayscale level r of the input video signal is higher than the minimum value, the relative intensity br of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_R of the liquid crystal panel **10**A is made to have the maximum value. Accordingly, the power consumption can be reduced. In the case where the grayscale level r is the minimum value, the relative intensity br of the backlight **20** is made to have the minimum value, and the grayscale level p_R of the liquid crystal panel **10**A is made to have the minimum value. Accordingly, the power consumption can be reduced, and the contrast ratio can be improved.

In addition, in the case where the grayscale level g of the input video signal is higher than the minimum value, the relative intensity bg of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_G of the liquid crystal panel **10**A is made to have the maximum value. In the case where the grayscale level g is the minimum value, the relative intensity bg of the backlight **20** is made to have the minimum value, and the grayscale level p_G of the liquid crystal panel **10**A is made to have the minimum value. Similarly, in the case where the grayscale level b of the input video signal is higher than the minimum value, the relative intensity bb of the backlight **20** is made to be higher than the minimum value, and the grayscale level p_B of the liquid crystal panel **10**A is made to have the maximum value. In the case where the grayscale level b is the minimum value, the relative intensity bb of the backlight **20** is made to have the minimum value, and the grayscale level p_B of the liquid crystal panel **10**A is made to have the minimum value.

In the case where all of the grayscale levels r, g, and b of the input video signal are higher than the minimum value, as is understood from the above description, all of the relative intensities br, bg, and bb of the backlight **20** are higher than the minimum value, and the grayscale level p_W of the liquid crystal panel **10**A is made to have the maximum value. Accordingly, the power consumption can be reduced. In the case where at least one of the grayscale levels r, g, and b of the input video signal has the minimum value, as is understood from the above description, at least one of the relative intensities br, bg, and bg of the backlight **20** is made to have the minimum value, and the grayscale level p_W of the liquid crystal panel **10**A is made to have the minimum value. Accordingly, the power consumption can be reduced, and the contrast ratio can be improved.

Thus, in the case where any of the grayscale levels r, g, and b of the input video signal has the minimum value, the corresponding one of the relative intensities br, bg, and bb of the backlight **20** also has the minimum value, and the corresponding one of the light sources **22**R, **22**G, and **22**B is turned off. In addition, in the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the relative intensities br, bg, and bb of the backlight **20** are also higher than the minimum value, so that the light sources **22**R, **22**G, and **22**B are turned on. In the case where any of the grayscale levels r, g, and b of the input video signal has the minimum value, the corresponding one of the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A is made to have the minimum value. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A have the maximum value.

In the liquid crystal display device **200**, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is set to be the same as the magnitude correlation among the luminance levels r, g, and b of the input video signal. For example, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b of the input video signal, respectively. The grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10** are set depending on the condition whether the grayscale levels r, g, and b of the input video signal are the minimum value, or not. In the case where the grayscale levels r, g, and b are the minimum value, the grayscale levels p_R, p_G, and p_B exhibit the minimum value. In the case where the grayscale levels r, g, and b are higher than the minimum value, the grayscale levels p_R, p_G, and p_B exhibit the maximum value. In another case where at least one of the grayscale levels r, g, and b is the minimum value, the grayscale level p_W exhibits the minimum value. In the case where all of the grayscale levels r, g, and b are higher than the minimum value, the grayscale level p_W exhibits the maximum value. For example, in the case where the grayscale levels (r, g, b) of the input video signal are (128, 128, 128), i.e. in the case where the normalized luminance is 0.216 in the input video signal, the grayscale levels (p_R, p_G, p_B, p_W) are (255, 255, 255, 255), and the relative intensities (br, bg, bb) of the backlight **20** are (0.216, 0.216, 0.216).

Herein FIG. **32** is referred to again. As described above, the active drive processing portion **32** generates a light source signal based on the input video signal. The light source signal indicates the relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B. The backlight driving circuit **38** generates a light source driving signal based on the light source signal. The light sources **22**R, **22**G, and **22**B of the backlight **20** are driven by the light source driving signal. At this time, the light sources **22**R, **22**G, and **22**B emit light with the relative intensities sr, sg, and sb, and the relative intensities of the backlight **20** are br, bg, and bb. In the case where any of the grayscale levels r, g, and b of the input video signal is the minimum value, the corresponding light sources **22**R, **22**G, and **22**B are turned off, and the corresponding relative intensities br, bg, and bb of the backlight **20** have the minimum value. In the case where the grayscale levels r, g, and b of the input video signal are higher than the minimum value, the light sources **22**R, **22**G, and **22**B are turned on, and the relative intensities br, bg, and bb of the backlight **20** exhibit values higher than the minimum value, respectively.

For example, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is equal to the magnitude correlation among the luminance levels r, g, and b of the input video signal. Specifically, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of br>bg>bb. In the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r<g<b, the relative intensities br, bg, and bb satisfy the relationship of br<bg<bb.

The liquid crystal data signal indicates red, green, and blue grayscale levels pr, pg, and pb. The grayscale levels pr, pg, and pb of the liquid crystal data signal are set, for example, based on the grayscale levels r, g, and b and the relative intensities br, bg, and bb. The grayscale levels r, g, and b of the input video signal are higher then the minimum value, respectively, the grayscale levels pr, pg, and pb of the liquid crystal data signal exhibit the maximum value. Alternatively, in the case where any of the grayscale levels r, g, and b of the input video signal is the minimum value, the corresponding grayscale levels pr, pg, and pb exhibit the minimum value.

The multi-primary color converting portion **34** generates a panel signal from the liquid crystal data signal. The multi-primary color converting portion **34** converts the grayscale levels pr, pg, and pb of the liquid crystal data signal to red, green, blue, and white grayscale levels p_1, p_2, p_3, and p_4, and generates a panel signal indicating the grayscale levels p_1, p_2, p_3, and p_4 as the grayscale levels p_R, p_G, p_B, and p_W.

The panel driving circuit **36** generates a panel driving signal based on the panel signal, thereby driving the liquid crystal panel **10**A. Across the liquid crystal layers LC_R, LC_G, LC_B, and LC_W in the liquid crystal panel **10**, voltages corresponding to the grayscale levels p_R, p_G, p_B, and p_W are applied.

In the above description, the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A are set in accordance with the grayscale levels r, g, and b of the input video signal. However, the present invention is not limited to this. The relative intensities br, bg, and bb of the backlight **20** are set in accordance with the grayscale levels r, g, and b of the input video signal, so that the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A may be set to have the maximum value irrespective of the grayscale levels r, g, and b of the input video signal. It is understood that the grayscale levels p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A are set in accordance with the grayscale levels r, g, and b of the input video signal, so that high contrast can easily be realized.

Next, with reference to FIG. **33**, the relative transmittance of the liquid crystal panel **10**A and relative intensity of the backlight **20** in the liquid crystal display device **200** will be described. FIG. **33** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A in the liquid crystal display device **200**.

Herein the input video signal indicates green. For example, the grayscale levels (the luminance levels) r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) are (0, 0.216, 0), and the grayscale levels (r, g, b) are (0, 128, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. As described above, the magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is equal to the magnitude correlation among the luminance levels r, g, and b of the input video signal, and the relative intensities br, bg, and bb satisfy the relationship of bg>br=bb=0. For example, the relative intensities (br, bg, bb) are (0, 0.216, 0).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 1, 0), and the grayscale levels (pr, pg, pb) are represented by (0, 255, 0) in the 255 grayscale notation. As described above, the luminance level r is expressed by the product of the relative intensity br and the transmittance level pr. Similarly, the luminance level g is expressed by the product of the relative intensity bg and the transmittance level pg. In addition, the luminance level b is expressed by the product of the relative intensity bb and the transmittance level pb.

The transmittance levels pr, pg, and pb are converted to relative transmittances p_R, p_G, p_B, and p_W by the multi-primary color conversion. In this case, the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 1, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_W) are represented by (0, 255, 0, 0) in the 255 grayscale notation. Thus, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b of the input video signal. A transmittance level of the transmittance levels pr, pg, and pb corresponding to a luminance level of the luminance levels r, g, and b of the input video signal which has the minimum value has the minimum value. A transmittance level of the transmittance levels pr, pg, and pb corresponding to a luminance level of the luminance levels r, g, and b which is higher than the minimum value has the maximum value. Accordingly, the power consumption of the backlight **20** can be reduced, and the contrast ratio can be increased.

Hereinafter the advantages of the liquid crystal display device **200** in this embodiment will be described as compared with the liquid crystal display device **700** in the comparative example 1 and a liquid crystal display device **900** in a comparative example 3.

Herein with reference to FIG. **34**, the liquid crystal display device **900** in the comparative example 3 will be described. FIG. **34**(*a*) shows a schematic diagram of the liquid crystal display device **900** in the comparative example 3. The liquid crystal display device **900** includes a liquid crystal panel **910** and a backlight **920**.

FIG. **34**(*b*) shows a schematic diagram of the liquid crystal panel **910**. Similarly to the liquid crystal panel **10**A, in the liquid crystal panel **910**, a pixel P has a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a white sub-pixel W. The liquid crystal panel **910** performs display with four primary colors. The size and the resolution of the liquid crystal panel **910** are substantially the same as those of the liquid crystal panel **710**. The size of the pixel P of the liquid crystal display device **900** is the same as that of the pixel P of the liquid crystal display device **700**.

The backlight **920** emits light of constant intensity in the driving of the liquid crystal display device **900**. In the case where the liquid crystal display device **900** displays white, liquid crystal layers LC_R, LC_G, LC_B, and LC_W exhibit the maximum transmittances, respectively. In the case where the liquid crystal display device **900** displays black, the liquid crystal layers LC_R, LC_G, LC_B, and LC_W exhibit the minimum transmittances, respectively. Thus, in the liquid crystal display device **900**, depending on the change of color indicated in the input video signal, the transmittances of the liquid crystal layers LC_R, LC_G, LC_B, and LC_W of the liquid crystal panel **910** are changed, and the luminance of each sub-pixel is changed, thereby representing various colors.

The control of the liquid crystal panel **910** and the backlight **920** is performed in the following manner. FIG. **34**(*c*) shows the liquid crystal display device **900** provided with a control circuit **930**. The control circuit **930** includes a multi-primary color converting portion **934**, a panel driving circuit **936**, and a backlight driving circuit **938**. The multi-primary color converting portion **934** converts the grayscale levels r, g, and b of the input video signal to grayscale levels p_R, p_G, p_B, and p_W of a panel signal. In general, the color phase of color represented by the grayscale levels r, g, and b of the input video signal is substantially the same as the color phase of color represented by the grayscale levels p_R, p_G, p_B, and p_W of the panel signal. In the driving of the liquid crystal display device **900**, the backlight driving circuit **938** drives the backlight **920** so as to emit light of constant intensity from the backlight **920**.

Table 17 shows the luminance ratios of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the yellow sub-pixel W in the liquid crystal display device **900** in the comparative example 3.

TABLE 17

	Luminance ratio
R	11.8%
G	29.6%
B	9.6%
Ws	49.0%
W	100%

FIG. **35** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **920**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_W of the liquid crystal panel **910** in the liquid crystal display device **900**.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), and the grayscale levels (r, g, b) are (0, 128, 0) in the 255 grayscale notation. In the liquid crystal display device **900**, the backlight **920** emits light of constant intensity irrespective of the color indicated in the input video signal. Herein the relative intensities (br, bg, bb) are indicated as (1, 1, 1).

In the liquid crystal display device **900**, the transmittance levels (the grayscale levels) pr, pg, and pb of the liquid crystal data signal are equal to the luminance levels (the grayscale levels) r, g, and b of the input video signal. Accordingly, as described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the transmittance levels pr, pg, and pb of the liquid crystal data signal also satisfy the relationship of pg>pr=pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (0, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (0, 0.216, 0), and the grayscale levels (pr, pg, pb) are (0, 128, 0) in the 255 grayscale notation.

In the liquid crystal display device **900**, multi-primary color conversion is performed. The relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **910** are (0, 0.216, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_W) are represented by (0, 128, 0, 0) in the 255 grayscale notation.

As is understood from the comparison FIG. **33**, and FIG. **10** and FIG. **35**, in the liquid crystal display devices **700** and **900**, the light of constant intensity emitted from the backlight **720** and **920** is modulated in the liquid crystal panels **710** and **910**. On the contrary, in the liquid crystal display device **200**, the light modulation is performed in the backlight **20**, and the liquid crystal panel **10**A makes the relative transmittance of the sub-pixel related to the light from the backlight **20** to be the maximum value, and makes the relative transmittance of the sub-pixel not related to the light from the backlight **20** to be the minimum value. Thus, in the liquid crystal display devices **700** and **900**, light of constant intensity is emitted from the backlight **720** and **920**. On the contrary, in the liquid crystal display device **200**, the light sources **22**R and **22**B are turned off in accordance with the input video signal, and additionally the intensity of the light source **22**G can be lowered. Accordingly, the power consumption of the backlight **20** can be reduced.

In the above description, the color indicated in the input video signal is green. Even if the color indicated in the input video signal is an arbitrary color, the power consumption can be reduced and the contrast ratio can be increased for the same reasons.

In some cases, in the liquid crystal display device **900** in the comparative example 3, a color of high brightness cannot be displayed. The case where the input video signal indicates orange, and more specifically, the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), and the grayscale levels (r, g, b) are (255, 128, 0) will be described.

First, in the liquid crystal display device **700** in the comparative example 1, as is described with reference to FIG. **13**, the grayscale levels (r, g, b) of the red, green, and blue sub-pixels are (255, 128, 0). In such a case, the normalized intensity is 0.368 ($=0.246\times(255/255)^{2.2}+0.566\times(128/255)^{2.2}+0.188\times(0/255)^{2.2}$) (see Table 6).

Next, with reference to FIG. **36**, the liquid crystal display device **900** in the comparative example 3 will be described. FIG. **36** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **920**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_W of the liquid crystal panel **910** in the liquid crystal display device **900**.

In the liquid crystal display device **900**, the backlight **920** emits light of constant intensity irrespective of the color indicated in the input video signal. Herein the relative intensities (br, bg, bb) of the backlight **920** are indicated as (1, 1, 1).

In the liquid crystal display device **900**, the transmittance levels (the grayscale levels) pr, pg, and pb of the liquid crystal data signal are equal to the luminance levels (the grayscale levels) r, g, and b of the input video signal, and the transmittance levels pr, pg, and pb of the liquid crystal data signal also satisfy the relationship of pr>pg>pb=0. Specifically, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 0.216, 0).

In the liquid crystal display device **900**, multi-primary color conversion is performed. The relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **910** are (1, 0.216, 0, 0), and the grayscale levels (p_R, p_G, p_B, p_W) are represented by (255, 128, 0, 0) in the 255 grayscale notation. The normalized luminance in the liquid crystal display device **900** is 0.182 ($=0.118\times(255/255)^{2.2}+0.296\times(128/255)^{2.2}+0.096\times(0/255)^{2.2}+0.490\times(0/255)^{2.2}$). Table 18 shows the grayscale levels of respective sub-pixels and the normalized luminance in the liquid crystal panel **910** of the liquid crystal display device **900**. Table 18 also shows the values of the liquid crystal display device **700** in the comparative example 1 for reference.

TABLE 18

	R	G	B	W	Normalized luminance
Grayscale level in Comparative example 1	255	128	0	—	0.368
Grayscale level in Comparative example 3	255	128	0	0	0.182

Thus, the normalized luminance of the liquid crystal display device **900** in the comparative example 3 is low, so that orange of high brightness cannot be displayed. It is considered that this is because in the case where the size of the pixel P of the liquid crystal display device **900** is the same as that of the pixel P of the liquid crystal display device **700**, the area of the red sub-pixel R, the green sub-pixel G, and the blue sub-pixel B in the liquid crystal panel **910** is smaller than the area of the red sub-pixel R, the green sub-pixel G, and the blue sub-pixel B in the liquid crystal panel **710**.

On the contrary, the liquid crystal display device **200** in this embodiment can display colors of high brightness as compared with the liquid crystal display device **900** in the comparative example 3.

Hereinafter with reference to FIG. **37**, the relative transmittance of the liquid crystal panel **10**A and the relative intensity of the backlight **20** in the liquid crystal display device **200** will be described. FIG. **37** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A in the liquid crystal display device **200**.

Herein the input video signal also indicates orange. Specifically, the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), and the grayscale levels (r, g, b) are (255, 128, 0) in the 255 grayscale notation.

The magnitude correlation among the relative intensities br, bg, and bb of the backlight **20** is the same as the magnitude correlation among the grayscale levels r, g, and b of the input video signal. Accordingly, in the case where the grayscale levels satisfy the relationship of r>g>b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of br>bg>bb=0. For example, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b. Accordingly, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the relative intensities (br, bg, bb) are (1, 0.216, 0). Table 19 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 19

Embodiment 3	br	bg	bb
Relative intensity of Backlight	1	0.216	0

In the liquid crystal display device **200**, the transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. In the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of r>g>b=0, the grayscale levels pr and pg have the maximum value, and the grayscale level pb has the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (1, 0.216, 0), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (1, 1, 0), and the grayscale levels (pr, pg, pb) are (255, 255, 0) in the 255 grayscale notation.

Thereafter, by the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (1, 1, 0, 1), and the grayscale levels (p_R, p_G, p_B, p_W) are (255, 255, 0, 255) in the 255 grayscale notation. Table 20 shows the grayscale levels of the liquid crystal panel **10**A. The grayscale level of 255 of the liquid crystal panel corresponds to the relative transmittance of 1, and the grayscale level of 0 of the liquid crystal panel corresponds to the relative transmittance of 0.

TABLE 20

Embodiment 3	Red sub-pixel	Green sub-pixel	Blue sub-pixel	White sub-pixel
Grayscale level of Liquid crystal panel	255	255	0	255

In the case where the liquid crystal panel **10**A and the backlight **20** are driven in the above-described way, the normalized luminance of the liquid crystal display device **200** is 0.371.

As is understood from the comparison between FIG. **36** and FIG. **37**, in the liquid crystal display device **900**, the light of constant intensity emitted from the backlight **920** is modulated in the liquid crystal panel **910**. On the contrary, in the liquid crystal display device **200**, the light sources **22**R and **22**G related to the color of orange to be displayed are turned on, and the light source **22**B which is not related to the color of orange to be displayed is turned off. In addition, the intensity of the light source **22**G is made lower than the maximum value. Since the backlight **20** performs such modulation, the power consumption of the backlight **20** can be reduced. In the liquid crystal display device **900**, the light emitted from the backlight **920** with constant intensity is modulated in the liquid crystal panel **910**. On the contrary, in the liquid crystal display device **200**, the light modulation is performed in the backlight **20**, and in addition, the liquid crystal panel **10**A makes the relative transmittance of the sub-pixel related to the light from the backlight **20** to be the maximum value, and makes the relative transmittance of the sub-pixel not related to the light from the backlight **20** to be the minimum value. Accordingly, the contrast ratio can be increased.

As described above, the normalized luminance of the liquid crystal display device **900** in the comparative example 3 is 0.182, and the normalized luminance of the liquid crystal display device **200** in this embodiment is 0.371. This is because in the liquid crystal display device **200**, the grayscale levels p_R, p_G, and p_W of the liquid crystal panel **10**A are the maximum value, and the light of the light sources **22**R and **22**G which are turned on is effectively transmitted through the liquid crystal panel **10**A. Accordingly, the liquid crystal display device **200** can display orange of high brightness.

In the above description, the color indicated in the input video signal is orange. Alternatively, the color indicated in the input video signal may be any other color.

(Embodiment 4)

Hereinafter a fourth embodiment of the liquid crystal display device of the present invention will be described. FIG. **38**(*a*) shows a schematic diagram of a liquid crystal display device **200**A in this embodiment. The liquid crystal display device **200**A includes a liquid crystal panel **10**A and a backlight **20**.

FIG. **38**(*b*) shows a schematic diagram of a pixel P in the liquid crystal panel **10**A. Herein a pixel P also includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a white sub-pixel W. As described above with reference to FIG. **1**(*d*) and FIG. **1**(*e*), the backlight **20** has a light source unit **22** including light sources **22**R, **22**G, and **22**B.

FIG. **39** shows a schematic diagram of the liquid crystal display device **200**A provided with a control circuit **30**A. The circuit control **30**A controls the liquid crystal panel **10**A and the backlight **20** based on an input video signal. The control circuit **30**A includes an active drive processing portion **32**, a multi-primary color converting portion **34**A, a panel driving circuit **36**, and a backlight driving circuit **38**. The control circuit **30**A has the same configuration as that of the control circuit **30** described above with reference to FIG. **32**, so that overlapping descriptions are omitted for avoiding verbose descriptions.

The active drive processing portion **32** generates a light source signal and a liquid crystal data signal based on the input video signal. The light source signal indicates the relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B. The relative intensities sr, sg, and sb of the light sources **22**R, **22**G, and **22**B are set based on the luminance levels r, g, and b of the input video signal. The backlight driving circuit **38** drives the light sources **22**R, **22**G, and **22**B of the backlight **20** based on the light source signal. At this time, light of relative intensities br, bg, and bb is emitted from the backlight **20**.

The active drive processing portion **32** generates a backlight signal from the light source signal. The backlight signal indicates the relative intensities br, bg, and bb of the backlight **20**. In the active drive processing portion **32**, the relative intensities br, bg, and bb of the backlight **20** are obtained from the relative intensities sr, sg, and sb. Thus, the relative intensities br, bg, and bb are set in accordance with the luminance levels r, g, and b of the input video signal. For example, the magnitude correlation among the relative intensities br, bg, and bb may be equal to the magnitude correlation among the luminance levels r, g, and b. Alternatively, the relative intensities br, bg, and bb may be substantially equal to the luminance levels r, g, and b.

Alternatively, the relative intensities br, bg, and bb may be determined in any other conditions based on the luminance levels r, g, and b. The relative intensities br, bg, and bb of the backlight **20** may be higher than the luminance levels r, g, and b in accordance with the input video signal. As described above, in the case where colors of all pixels are the same in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may be equal to the luminance levels r, g, and b of the input video signal. On the other hand, in the case where pixels exhibit different colors in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may sometimes be higher than the luminance levels r, g, and b of the input video signal. Specifically, in the input video signal, in the case where the red grayscale levels of a plurality of pixels corresponding to a certain light source unit **22** are different, the relative intensity br of the backlight **20** is set in accordance with the maximum value of the grayscale level r, and the relative intensity br is higher than the grayscale levels r of the other pixels. Similarly, in the input video signal, in the case where grayscale levels of green and blue of a plurality of pixels corresponding to the light source unit **22** are different, the relative intensities bg and bb of the backlight **20** are set in accordance with the maximum value of the grayscale levels g and b, and the relative intensities bg and bb are higher than the grayscale levels bg and bb of the other pixels.

Alternatively, even in the case where the colors of all pixels in the input video signal are the same, if the relative intensities br, bg, and bb of the backlight **20** are made to be equal to the luminance level r, g, and b of the input video signal, the display characteristics such as the color shift and viewing angle characteristics may sometimes be deteriorated. In such a case, even if the colors in all pixels are the same in the input video signal, the relative intensities br, bg, and bb of the backlight **20** may be set to be higher than the luminance level r, g, and b of the input video signal.

Thus, the relative intensities br, bg, and bb are determined based on the luminance levels r, b, and b.

The multi-primary color converting portion **34**A converts the grayscale levels pr, pg, and pb of the liquid crystal data signal to grayscale levels p_1, p_2, p_3, and p_4 of red, green, blue, and white. As described above, the color phase (chromaticity) of color indicated by the grayscale levels pr, pg, and pb before the conversion is substantially the same as the color phase (chromaticity) of color indicated by the grayscale levels p_1, p_2, p_3, and p_4 after the conversion.

Thereafter the multi-primary color converting portion **34**A generates a panel signal indicating the grayscale levels p_1, p_2, p_3, and p_4 as the grayscale levels p_R, p_G, p_B, and p_W. Alternatively, the multi-primary color converting portion **34**A may set the grayscale levels p_1, p_2, and p_3, as the grayscale levels p_R, p_G, and p_B, respectively, and may set p_4' which is higher than the grayscale level p_4 as the grayscale level p_W.

For example, the multi-primary color converting portion **34**A may set the grayscale level p_4' based on the backlight signal. As described later, as the grayscale level p_4' is increased, the chromaticity is shifted in accordance with the increase of normalized luminance. For this reason, it is preferred that the grayscale level p_4' may be set to such an extent that the shift of chromaticity is not too large.

For example, the multi-primary color converting portion **34**A sets the grayscale level p_4' based on the relative intensities br, bg, and bb of the backlight **20**. The grayscale level p_4' may be set to be a constant value based on the relative intensities br, bg, and bb of the backlight **20**, or may be continuously varied in accordance with the relative intensities br, bg, and bb. Thus, the multi-primary color converting portion **34**A may generate a panel signal based on not only the liquid crystal data signal but also the backlight signal. The panel driving circuit **36** drives the liquid crystal panel **10**A based on the panel signal indicating the grayscale levels p_R, p_G, p_B, and p_W.

Hereinafter the liquid crystal display device **200**A in the case where the input video signal indicates green will be described. For example, the grayscale levels (r, g, b) of the input video signal are (0, 255, 0) in the 255 grayscale notation. Herein the relative intensities br, bg, and bb are substantially the same as the luminance levels r, g, and b, and the multi-primary color converting portion **34**A generates a panel signal based on not only the liquid crystal data signal but also the backlight signal. In this case, the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0).

As the result of the conversion of the grayscale levels pr, pg, and pb by the multi-primary color converting portion **34**A, the grayscale levels (p_1, p_2, p_3, p_4) of the red, green, blue, and white sub-pixels are (0, 255, 0, 0). The chromaticity of color indicated by the grayscale levels pr, pg, and pb is substantially the same as the chromaticity of color indicates by the grayscale levels p_1, p_2, p_3, and p_4.

Thereafter, the multi-primary color converting portion **34**A sets the grayscale level p_4' based on the relative intensities br, bg, and bb of the backlight **20**. Herein since the difference between the relative intensities br and bg is large, the multi-primary color converting portion **34**A sets the grayscale level p_4' which is higher than the grayscale level p_4 as the grayscale level p_W. Accordingly, the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, p_4') in the 255 grayscale notation. Herein the grayscale level p_4' is $0<p_4'\leq 255$, and the relative transmittance p_4' is $0<p_4'\leq 1$. Thus, in the case where the input video signal indicates green, in the liquid crystal display device **200**A, the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), and the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10** are (0, 1, 0, p_4'), and the grayscale levels (p_R, p_G, p_B, p_W) are represented as (0, 255, 0, p_4') in the 255 grayscale notation.

In the liquid crystal display device **200**A, in the case where the light source **22**G of the backlight **20** is turned on, and the light sources **22**R and **22**B are turned off, the light from the backlight **20** is transmitted through not only the green sub pixel G but also the white sub-pixel W. Accordingly, the normalized luminance can be efficiently increased.

Hereinafter with reference to FIG. **40**, the normalized luminance of the liquid crystal display device **200**A will be described.

FIG. **40**(*a*) shows an emission spectrum of the backlight **20**. Herein the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0), and the light source **22**G is turned on. The emission spectrum has the peak wavelength of about 520 nm.

FIG. **40**(*b*) shows a transmission spectrum of the liquid crystal panel **10**A. Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 0, 0, 255), and the light is transmitted through the white sub-pixel W. Accordingly, the liquid crystal panel **10**A transmits light of a full range of wavelengths.

FIG. **40**(*c*) shows an emission spectrum of the liquid crystal display device **200**A in the case where the light of the spectrum shown in FIG. **40**(*a*) is emitted from the backlight **20** and the light is transmitted with the spectrum shown in FIG. **40**(*b*) in the liquid crystal panel **10**A. Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 0, 0, 255) and the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). In this case, the intensity of light emitted from the white sub-pixel W is mainly expressed by the product of the intensity of light from the light source **22**G in the backlight **20** and the transmittance of the white sub-pixel W. The emission spectrum also has the peak wavelength of about 520 nm.

FIG. **40**(*d*) shows an emission spectrum of the liquid crystal display device **200**A in the case where the light of the spectrum shown in FIG. **40**(*a*) is emitted from the backlight **20** and the light is transmitted with the spectra shown in both of FIG. **30**(*b*) and FIG. **40**(*b*) in the liquid crystal panel **10**A. Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 255), and the relative intensities (br, bg, bb) of the backlight **20** are (0, 1, 0). In this case, the intensity of light emitted from the liquid crystal display device **200**A is expressed by the sum of the intensity of light emitted from the light source **22**G and transmitted through the green sub-pixel G and the intensity of light transmitted through the sub-pixel W. Thus, green of high brightness can be displayed.

Herein the advantages of the liquid crystal display device **200**A in this embodiment will be described as compared with the liquid crystal display devices **700** and **900** in the comparative examples 1 and 3. First, the liquid crystal display device **700** in the first comparative example 1 will be described.

Herein the color indicated in the input video signal is green, and the grayscale levels (r, g, b) are (0, 255, 0) in the 255 grayscale notation. In the liquid crystal display device **700** in the comparative example 1, the light of constant intensity is emitted from the backlight **720**. Herein the relative intensities (br, bg, bb) of the backlight **720** are indicated by (1, 1, 1).

The grayscale levels (pr, pg, pb) of the red, green, and blue sub-pixels in the liquid crystal panel **710** are equal to the grayscale levels (r, g, b) of the input video signal and (0, 255, 0). In this case, the normalized luminance in the liquid crystal display device **700** is 0.566 ($=0.246\times(0/255)^{2.2}+0.566\times(255/255)^{2.2}+0.188\times(0/255)^{2.2}$).

Next, the liquid crystal display device **900** in the comparative example 3 will be described. Herein the color indicated in the input video signal is green, and the grayscale levels (r, g, b) are (0, 255, 0) in the 255 grayscale notation. In the liquid crystal display device **900** in the comparative example 3, the light of constant intensity is emitted from the backlight **920**. Herein the relative intensities (br, bg, bb) of the backlight **920** are indicated by (1, 1, 1).

The grayscale levels (pr, pg, pb) of the liquid crystal data signal are equal to the grayscale levels (r, g, b) of the input video signal and (0, 255, 0). In the liquid crystal display device **900** in the comparative example 3, multi-primary color conversion is performed. The grayscale levels (p_R, p_G, p_B, p_W) are (0, 255, 0, 0) in the 255 grayscale notation. In this case, the normalized luminance in the liquid crystal display device **900** is 0.295 ($=0.118\times(0/255)^{2.2}+0.296\times(255/255)^{2.2}+0.096\times(0/255)^{2.2}+0.490\times(0/255)^{2.2}$). Table 21 shows the grayscale levels of respective sub-pixels in the liquid crystal panel **910**. Table 21 also shows the values of the liquid crystal display device **700** in the comparative example 1 for reference.

TABLE 21

	R	G	B	W	Normalized luminance
Grayscale level in Comparative example 1	0	255	0	—	0.566
Grayscale level in Comparative example 3	0	255	0	0	0.295

Thus, the normalized luminance of the liquid crystal display device **900** in the comparative example 3 is low, so that the liquid crystal display device **900** cannot display green of high brightness.

In the above-described liquid crystal display device **200**, in the case where the input video signal indicates green, the light source **22**G of the backlight **20** is turned on, and the green sub-pixel G transmits the light. For example, as described above with reference to FIG. **30**, in the case where the grayscale levels (r, g, b) of the input video signal are (**0**, **255**, **0**, the relative intensities (br, bg, bb) of the backlight **20** are (**0**, **1**, **0**), the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (**0**, **1**, **0**, **0**), and the grayscale levels (p_R, p_G, p_B, p_W) are represented as (**0**, **255**, **0**, **0**) in the 255 grayscale notation. In this case, light of the spectrum shown in FIG. **30**(*c*) is emitted. However, high brightness cannot be obtained only by the light in some cases.

On the contrary, the liquid crystal display device **200**A in this embodiment can display green of high brightness. Hereinafter the normalized luminance of the liquid crystal display device **200**A will be described. Herein the color indicated in the input video signal is green, and the luminance levels (r, g, b) are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

Herein the relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. Table 22 shows the relative intensities (br, bg, bb) of the backlight **20**.

TABLE 22

Embodiment 4	br	bg	bb
Relative intensity of Backlight	0	1	0

Herein, as described above, the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (**0**, **1**, **0**, p_4'), and the grayscale levels (p_R, p_G, p_B, p_W) are (**0**, **255**, **0**, p_4') in the 255 grayscale notation. Table 23 shows the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, and the white sub-pixel W in the liquid crystal panel **10**A.

TABLE 23

Embodiment 4	R	G	B	W
Grayscale level of Liquid crystal panel	0	255	0	p_4'

As described above, the relative transmittance p_4' is $0<p_4'\leq 1$, and the grayscale level p_4' is $0<p_4'\leq 255$. As the grayscale level p_4' is increased, the improvement effect of the normalized luminance is large. However, if the grayscale level p_4' is too high, the chromaticity of color displayed by the liquid crystal display device **200**A may sometimes be largely shifted. In addition, if the grayscale level p_4' is low, the shift of chromaticity is suppressed, but the improvement effect of the normalized luminance is also reduced. For example, in the case where the grayscale level p_4' is **234**, the normalized luminance of the liquid crystal display device **200**A is 0.566 which is equal to that in the liquid crystal display device **700** in the comparative example 1. The grayscale level of **234** corresponds to the relative transmittance **0.828**.

FIG. **41** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_Y of the liquid crystal panel **10**A in the liquid crystal display device **200**A. Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), and the grayscale levels (r, g, b) are (0, 255, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b of the input video signal. In the case where the luminance levels r, g, and b satisfy the relationship of g>r=b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationship of bg>br=bb=0. Specifically, the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), the relative intensities (br, bg, bb) are (0, 1, 0).

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (**0**, **1**, **0**), and the grayscale levels (pr, pg, pb) are represented as (0, 255, 0) in the 255 grayscale notation. In this case, by the multi-primary color conversion, the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 1, 0, 0.828), and the grayscale levels (p_R, p_G, p_B, p_W) are represented as (0, 255, 0, 234) in the 255 grayscale notation.

In the above description, the color indicated in the input video signal is green. However, the present invention is not limited to this. The color indicated in the input video signal may be red. For example, also in the case where the grayscale levels of the input video signal satisfy the relationship of r>g=b=0, the relative intensity br of the backlight **20** is made to be higher than the minimum value and not only the grayscale level p_R but also the grayscale level p_W in the liquid crystal panel **10**A are made to be higher than the minimum value. Accordingly, red of high brightness can be displayed. Alternatively, the color indicated in the input video signal may be blue. For example, also in the case where the grayscale levels of the input video signal satisfy the relationship of b>r=g=0, the relative intensity bb of the backlight **20** is made to be higher than the minimum value, and not only the grayscale level p_R but also the grayscale level p_W in the liquid crystal panel **10**A are made to be higher than the minimum value. Accordingly, blue of high brightness can be displayed.

In the above description, the setting of the grayscale level p_4' is performed in the case where two of the relative intensities br, bg, and bb are the minimum value and the remaining one is higher than the minimum value. However, the present invention is not limited to this. Alternatively, in the case where at least two of the relative intensities br, bg, and bb are higher than the minimum value, the setting of the grayscale level p_4' may be performed.

In the above description, the relative intensities br, bg, and bb of the backlight **20** are substantially equal to the luminance levels r, g, and b of the input video signal. However, the present invention is not limited to this.

Hereinafter the liquid crystal display device **200**A will be described with reference to FIG. **42**. FIG. **42** shows luminance levels r, g, and b of the input video signal, relative intensities br, bg, and bb of the backlight **20**, transmittance levels pr, pg, and pb of the liquid crystal data signal, and relative transmittances p_R, p_G, p_B, and p_W of the liquid crystal panel **10**A in the liquid crystal display device **200**A.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0).

The relative intensities br, bg, and bb of the backlight **20** are set based on the luminance levels r, g, and b. In the case where the luminance levels r, g, and b satisfy the relationship of g>r=b=0, the relative intensities br, bg, and bb of the backlight **20** satisfy the relationships of bg≥br≥0 and bg≥bb≥0. For example, in the case where the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), the relative intensity bg, is 1, the relative intensity br is 0≤br≤1, and the relative intensity bb is 0≤bb≤1.

The transmittance levels pr, pg, and pb of the liquid crystal data signal are set based on the luminance levels r, g, and b of the input video signal. As described above, in the case where the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the grayscale level pg corresponding to the luminance level g has the maximum value, and the grayscale levels pr and pb corresponding to the luminance levels r and b have the minimum value. For example, in the case where the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), the transmittance levels (pr, pg, pb) of the liquid crystal data signal are (**0**, **1**, **0**), and the grayscale levels (pr, pg, pb) are represented by (0, 255, 0) in the 255 grayscale notation.

Next, multi-primary color conversion is performed. Herein the relative transmittances (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are **0**, **1**, **0**, **0**.**828**), and the grayscale levels (p_R, p_G, p_B, p_W) are represented as (0, 255, 0, 234) in the 255 grayscale notation. Herein similarly to the description with reference to FIG. **42**, the relative transmittances (p_R, p_G, p_B, p_Y) are (0, 1, 0, 0.828). However since the relative intensities br and bb of the backlight **20** are higher than the minimum value, the relative transmittance p_W may be lower than 0.828. As described above, in the case where the input video signal indicates green, not only the relative intensity bg but also the relative intensities br and/or bb of the backlight **20** may be higher than the minimum value.

In the above description, the color indicated in the input video signal is green. However, the present invention is not limited to this. The color indicated in the input video signal may be red. In this case, even when the grayscale levels of the input video signal satisfy the relationship of r>g=b=0, not only the relative intensity br but also the relative intensities bg and/or bb of the backlight **20** may be higher than the minimum value, and the grayscale levels p_R and p_W of the liquid crystal panel **10**A may be higher than the minimum value. Alternatively, the color indicated in the input video signal may be blue. In this case, the grayscale levels of the input video signal satisfy the relationship of b>r=g=0, not only the relative intensity bb but also the relative intensities br and/or bg of the backlight **20** may be higher than the minimum value, and the grayscale levels p_B and p_W of the liquid crystal panel **10**A may be higher than the minimum value.

Thus, in the case where the color indicated in the input video signal is green, not only the relative intensity bg but also the relative intensities br and/or bb of the backlight **20** may be higher than the minimum value.

Hereinafter with reference to FIG. **43**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensities br and bb of the backlight **20** in the liquid crystal display device **200**A will be described. Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), and the grayscale levels (r, g, b) are (0, 255, 0).

FIG. **43**(*a*) shows the variation of chromaticity. In FIG. **43**(*a*), the axis of abscissa indicates chromaticity x and the axis of ordinate indicates chromaticity y. FIG. **43**(*b*) shows the variation of normalized luminance. In FIG. **43**(*b*), the axis of abscissa indicates the relative intensities br and bb of the backlight **20** (br=bb), and the axis of ordinate indicates the normalized luminance. Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 0), and the relative intensity bg of the backlight **20** is 1.

As shown in FIG. **43**(*a*), when the relative intensities br and bb are 1, the chromaticity x and the chromaticity y are substantially the same as those when the relative intensities br and bb are 0. In the liquid crystal panel **10**A, the green sub-pixel G transmits light, and the other sub-pixels block out light, so that even if the relative intensities br and bb of the backlight **20** are increased, the light emitted from the liquid crystal panel **10**A is hardly affected. The emission spectra of the light sources **22**R and **22**B slightly overlap the transmission spectrum of the green sub-pixel G, and the intensity of light on the longer wavelength side and the shorter wavelength side of the light emitted from the liquid crystal panel **10**A is slightly increased due to the increase of the relative intensities br and bb of the backlight **20**. Thus, strictly speaking, as the relative intensities br and bb are increased, the chromaticity x and the chromaticity y are both slightly shifted.

As shown in FIG. **43**(*b*), the normalized luminance when the relative intensities br and bb are 1 is substantially the same as that when the relative intensities br and bb are 0. As described above, in the liquid crystal panel **10**A, the green sub-pixel G transmits light, and the other sub-pixels block out light, so that even if the relative intensities br and bb of the backlight **20** are increased, the light emitted from the liquid crystal panel **10**A is hardly affected.

As described above, in the case where not only the green sub-pixel G but also the white sub-pixel W transmit light in the liquid crystal panel **10**A, the chromaticity x, the chromaticity y, and the normalized luminance are varied respectively in accordance with the increase of the relative intensities br and bb.

With reference to FIG. **44**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensity br of the backlight **20** in the liquid crystal display device **100**A will be described. FIG. **44**(*a*) shows the variation of chromaticity, and FIG. **44**(*b*) shows the variation of normalized luminance. For reference, FIG. **44**(*b*) also shows the normalized luminance when the grayscale level p_W is zero.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (**0**, **1**, **0**), and the grayscale levels (r, g, b) are (0, 255, 0). Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 71), and the relative intensity bg of the backlight **20** is 1.

As shown in FIG. **44**(*a*), by increasing the relative intensities br and bb of the backlight **20**, the chromaticity x and the chromaticity y are relatively largely shifted. This is because not only the green sub-pixel G transmits light in the liquid crystal panel **10**A but also the white sub-pixel W transmits light to some extent, so that the intensity of light on the longer wavelength side and the shorter wavelength side of the light emitted from the liquid crystal panel **10**A is increased due to the increase of the relative intensities br and bb.

As shown in FIG. **44**(*b*), the normalized luminance when the grayscale level p_W is 71 is slightly larger than the normalized luminance when the grayscale level p_W is 0. This is because not only the green sub-pixel G but also the white sub-pixel W transmit light in the liquid crystal panel **10**A, as described above. The grayscale level p_W in the liquid crystal panel **10**A is relatively low, so that the influence on the normalized luminance is relatively small.

Next, with reference to FIG. **45**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensities br and bb of the backlight in the liquid crystal display device **200**A will be described. FIG. **45**(*a*) shows the variation of chromaticity, and FIG. **45**(*b*) shows the variation of normalized luminance. For reference, FIG. **45**(*b*) also shows the normalized luminance when the grayscale level p_W is zero.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0). Herein the grayscale levels (p_R, p_G, p_B, p_W) of the liquid crystal panel **10**A are (0, 255, 0, 234), and the relative intensity bg of the backlight **20** is 1.

As shown in FIG. **45**(*a*), due to the increase of the relative intensities br and bb of the backlight **20**, the chromaticity x and the chromaticity y are further largely shifted. This is because not only the green sub-pixel G but also the white sub-pixel W transmit light in the liquid crystal panel **10**A, so that the intensity of light on the longer wavelength side and the shorter wavelength side of the light emitted from the liquid crystal panel **10**A is largely increased due to the increase of the relative intensities br and bb.

As shown in FIG. **45**(*b*), the normalized luminance when the relative intensities br and bb are 1 is larger than the normalized luminance when the relative intensities br and bb are 0. This is because the grayscale level p_W in the liquid crystal panel **10**A is relatively high, so that the influence on the normalized luminance is large in accordance with the increase of the relative intensities br and bb. In addition, the normalized luminance when the grayscale level p_W is **234** is larger than the normalized luminance when the grayscale level p_W is 71.

As is understood from the comparison between FIG. **44** and FIG. **45**, in the case where the grayscale level p_W is small, the variation of chromaticity is relatively small, but the improvement effect of the normalized luminance is relatively small. On the contrary, in the case where the grayscale level p_W is large, the improvement effect of the normalized luminance is relatively large, and the variation of chromaticity is also relatively large.

In the above description, irrespective of the variation of the relative intensities br and bb of the backlight **20**, the grayscale level p_W in the liquid crystal panel **10**A is constant. However the present invention is not limited to this. The grayscale level p_W in the liquid crystal panel **10**A (in addition, the grayscale levels p_R and p_G, as necessary) may be varied in accordance with the change of the relative intensities br and bb of the backlight **20**.

With reference to FIG. **46**, the variations of chromaticity and normalized luminance in accordance with the change of the relative intensities br and bb of the backlight in the liquid crystal display device **200**A will be described. FIG. **46**(*a*) shows the variation of chromaticity, and FIG. **46**(*b*) shows the variation of normalized luminance. For reference, FIG. **45**(*b*) also shows the normalized luminance when the grayscale level p_W is 0, 71, and 234.

Herein the input video signal also indicates green. For example, the luminance levels r, g, and b of the input video signal satisfy the relationship of g>r=b=0, the luminance levels (r, g, b) of the input video signal are (0, 1, 0), and the grayscale levels (r, g, b) are (0, 255, 0). Herein the grayscale levels p_R, p_G, and p_B, of the liquid crystal panel **10**A are 0, 255, 0, respectively, and the grayscale level p_W is not less than 71 and not more than 234. The relative intensity bg of the backlight **20** is 1.

Herein in the case where the relative intensities br and bb are 0, the grayscale level p_W of the liquid crystal panel **10**A is 234, and the grayscale level p_W is reduced in accordance with the increase of the relative intensities br and bb. In the case where the relative intensities br and bb are 1, the grayscale level p_W of the liquid crystal panel **10**A is **71**.

As shown in FIG. **46**(*a*), the chromaticity is slightly shifted due to the increase of the relative intensities br and bb of the backlight **20**, but the shift amount is relatively small. Herein the grayscale level p_W is decreased in accordance with the increase of the relative intensities br and bb, so that the shift of chromaticity can be reduced.

As shown in FIG. **46**(*b*), in the case where the relative intensities br and bb are **0**, the improvement effect of the normalized luminance is large. On the contrary, as the relative intensities br and bb are increased, the improvement effect of the normalized luminance is reduced. Thus, in accordance with the increase of the relative intensities br and bb, the grayscale level p_W is reduced, thereby realizing the improvement of normalized luminance and the suppression of chromaticity shift.

In the above description, in the case where the intensities of light emitted from the light sources **22**R, **22**G, and **22**B of each light source unit **22** are equal to each other, light of constant intensity is emitted from the backlight **20** to respective pixels P of the liquid crystal panels **10** and **10**A. However, the present invention is not limited to this. Even in the case where the intensities of light emitted from the light sources **22**R, **22**G, and **22**B of each light source unit **22** are equal to each other, the intensity of light emitted from the backlight **20** may be different depending on the pixels P of the liquid crystal panels **10** and **10**A. For example, even if the intensities of light emitted from the light sources **22**R, **22**G, and **22**B of each light source unit **22** are constant, in the case where the intensity of light in the center of the light irradiation area of the light source unit **22** is different from the intensity of light in an outer circumferential portion of the light irradiation area of the light source unit **22** in the backlight **20**, the voltages applied across the liquid crystal layers LC_R, LC_G, LC_B, LC_Y and LC_W of the pixel P corresponding to the center of the light irradiation area may be different from the voltages applied across the liquid crystal layers LC_R, LC_G, LC_B, LC_Y and LC_W of the pixel P corresponding to the outer circumferential portion of the light irradiation area in the liquid crystal panel **10**.

In the above description, the light source units **22** are provided in a matrix having a plurality of rows and a plurality of columns in the backlight **20**. However the present invention is not limited to this. Alternatively, two light source units **22** may be arranged in the horizontal direction, or in the vertical direction. Alternatively, a single light source unit **22** may be provided in the backlight **20**.

In the above description, the liquid crystal panel is of a normally black type. However the present invention is not limited to this. The liquid crystal panel may be of a normally white type. In such a case, if the applied voltage is low, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, the yellow sub-pixel Ye, and the white sub-pixel W are increased. If the applied voltage is high, the transmittances of the red sub-pixel R, the green sub-pixel G, the blue sub-pixel B, the yellow sub-pixel Ye, and the white sub-pixel W are lowered.

In the above description, a pixel P in the liquid crystal panel **10** includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a yellow sub-pixel Ye, and a pixel P in the liquid crystal panel **10**A includes a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, and a white sub-pixel W. However the present invention is not limited to this. Instead of the yellow sub-pixel Ye or the white sub-pixel W, the pixel P may include a cyan sub-pixel C or a magenta sub-pixel M.

In the above description, in the liquid crystal panels **10** and **10**A, a pixel P includes four sub-pixels. However the present invention is not limited to this. The pixel P may include five or more sub-pixels. For example, a pixel P may include a red sub-pixel R, a green sub-pixel G, a blue sub-pixel B, a yellow sub-pixel Ye, and a cyan sub-pixel C.

In the liquid crystal panels **10** and **10**A, at least one of the back substrate **16***a* and the front substrate **16***b* may include an alignment film. Herein the alignment film is a vertical alignment film, and liquid crystal molecules are processed so as to have a pre-tilt angle less than 90 degrees (typically about 85 degrees or more). The pre-tilt angle is an angle formed by a main surface of the alignment film and a long axis of the liquid crystal molecule. By the alignment film, the pre-tilt direction of liquid crystal molecules is defined.

As a method for forming such an alignment film, a method for performing a rubbing process, a method for performing a photo-alignment process, a method in which a minute structure is previously formed as undercoating of the alignment film, and the minute structure is reflected on the surface of the alignment film, a method in which an inorganic substance such as SiO is obliquely deposited, so as to form an alignment film having a minute structure on its surface are known. From the point of view of the mass productivity, the rubbing process or the photo-alignment process may be preferable. Especially in the photo-alignment process, the alignment process is performed in a noncontact manner, so that static electricity due to friction is not generated unlike the rubbing process, thereby improving the yield. In addition, as disclosed in International Publication No. WO 2006/121220, by using a photo-alignment film including a photosensitive radical, the variation of pre-tilt angles can be controlled to be 1 degree or less. As the photosensitive radical, it is preferred to include at least one of photosensitive radicals selected from a group of the 4-chalcone radical, the 4'-chalcone radical, the coumarin radical, and the cinnamoyl radical.

The liquid crystal panels **10** and **10**A may be a panel of so-called MVA (Multi-domain Vertical Alignment) mode. In the liquid crystal panels **10** and **10**A of MVA mode, linear slits formed on the electrode or linear dielectric projections (ribs) formed on the electrode on the side of the liquid crystal layer are arranged, on a pair of substrates which are opposed with the liquid crystal layer interposed therebetween, in parallel and alternately when viewed from the normal direction of the substrate, thereby regulating the orientation of directors of liquid crystal domains formed when a voltage is applied. The orientation of liquid crystal domains is a direction orthogonal to the direction in which the linear slits or dielectric projections (hereinafter they are collective referred to as "linear structures") extend. In the MVA mode, scanning lines may be disposed so as to overlap the boundary of different liquid crystal domains.

The liquid crystal panels **10** and **10**A may be a panel of PSA mode. The Polymer Sustained, Alignment Technology (hereinafter referred to as "PSA technology") is disclosed, for example, in Japanese Laid-open Patent publication No. 2002-357830, Japanese Laid-open Patent Publication No. 2003-177418, Japanese Laid-open Patent Publication No. 2006-78968, and K. Hanaoka et al. "A New MVA-LCD by Polymer Sustained Alignment Technology", SID 04 DIGEST 1200-1203 (2004). The entire contents of these four documents are incorporated by reference in this specification.

The PSA technology is a technology in which a small amount of polymerizable compound (e.g. photopolymerizable monomer or oligomer) is mixed into a liquid crystal material, and then after a liquid crystal panel is assembled, the polymerizable compound is irradiated with activation energy rays (e.g. ultraviolet rays) in the condition where a predetermined voltage is applied across the liquid crystal layer, so that the polymer is generated, thereby controlling the pre-tilt angle of liquid crystal molecules. The alignment condition of liquid crystal molecules when the polymer is generated is maintained (memorized) after the voltage is removed (in a condition where any voltage is not applied). Herein the layer formed by the polymer is referred to as an alignment maintaining layer. The alignment maintaining layer is formed on the surface of the alignment film (on the side of the liquid crystal layer). However, the alignment maintaining layer does not necessarily have the shape for covering the surface of the alignment film, or the alignment maintaining layer may be polymer particles which discretely exist.

The liquid crystal panels **10** and **10**A in the PSA mode can be obtained by applying the above-described PSA technology, for example. Although not shown in the figure, in the case where the PSA technology is applied, each electrode (the pixel electrode) **12***a* may include a cross-shaped stem portion disposed so as to overlap a polarizing axis of a pair of polarizing plates and a plurality of branch portions extending in the substantially 45-degree direction from the cross-shaped stem portion. Specifically, the branch portions extend in the directions of 45 degrees, 135 degrees, 225 degrees, and 315 degrees from the stem portion. Liquid crystal molecules in the liquid crystal layer of the vertical alignment type (the dielectric anisotropy is negative) are tilted in directions in which the respective branch portions extend by means of the oblique electric fields from the stem portion and the branch portions. This is because the oblique electric field from the branch portions extending in parallel to each other acts on the liquid crystal molecules so as to be tilted in the direction perpendicular to the direction in which the branch portions extend, and the oblique electric field from the stem portion acts on the liquid crystal molecules so as to be tilted in the directions in which the respective branch portions extend. If the PSA technology is utilized, the orientation of the liquid crystal molecules formed when a voltage is applied across the liquid crystal layer can be stabilized. Even in the PSA mode, the scanning line may be disposed so as to overlap the boundary between different liquid crystal domains.

Alternatively, the liquid crystal panels **10** and **10**A may be a panel of CPA mode. For example, the pixel electrode **12***a* has a shape with high symmetry, and liquid crystal molecules in each liquid crystal domain may be oriented in an axis symmetric manner (in a radially tilted manner) by the voltage application across the liquid crystal layer LC.

The liquid crystal panels **10** and **10**A may have a plurality of regions which can exhibit different luminance. Especially in the case where each sub-pixel performs display of intermediate grayscales, different regions in each sub-pixel exhibit different luminance, so that the viewing angle dependency of the gamma characteristics can be improved.

In the above-described liquid crystal panels **10** and **10**A, the voltage is applied across the liquid crystal layer LC by means of the electrodes **12**a and **12**b provided in the back substrate **16**a and the front substrate **16**b, respectively. However, the present invention is not limited to this. Alternatively, in the liquid crystal panels **10** and **10**A, the voltage may be applied in a horizontal direction parallel to the in-plane of the liquid crystal layer. For example, the liquid crystal panels **10** and **10**A may be a panel of IPS (In Plane Switching) mode.

INDUSTRIAL APPLICABILITY

The liquid crystal display device of the present invention can perform display of wide color reproduction range with low power consumption.

REFERENCE SIGNS LIST

10, **10**A Liquid crystal panel
20 Backlight
22 Light source unit
22R Red light source
22G Green light source
22B Blue light source
30, **30**A Control circuit
100, **100**A, **200**, **200**A Liquid crystal display device

The invention claimed is:

1. A liquid crystal display device comprising:
a liquid crystal panel having a plurality of pixels;
a backlight having at least one light source unit that emits light to the liquid crystal panel; and
a control circuit that controls the liquid crystal panel and the backlight based on an input video signal; wherein
each of the plurality of pixels has four or more sub-pixels;
the four or more sub-pixels include a red sub-pixel, a green sub-pixel, a blue sub-pixel, and a yellow sub-pixel;
the light source unit includes a red light source, a green light source, and a blue light source; and
a magnitude correlation between relative intensities of the red light source, the green light source, and the blue light source has a same magnitude correlation between respective relative intensities of red, green, and blue grayscale levels indicated in the input video signal.

2. The liquid crystal display device of claim **1**, wherein the red light source, the green light source, and the blue light source are a red light emitting diode, a green light emitting diode, and a blue light emitting diode, respectively.

3. The liquid crystal display device of claim **1**, wherein the control circuit includes:
an active drive processing portion that generates a light source signal and a liquid crystal data signal based on the input video signal;
a multi primary color converting portion that generates a panel signal from the liquid crystal data signal;
a panel driving circuit that drives the liquid crystal panel based on the panel signal; and
a backlight driving circuit that drives the backlight based on the light source signal.

4. The liquid crystal display device of claim **3**, wherein the active drive processing portion generates a backlight signal from the light source signal, and the multi primary color converting portion generates the panel signal based on the backlight signal and the liquid crystal data signal.

5. The liquid crystal display device of claim **1**, wherein relative intensities of the red light source, the green light source, and the blue light source of the light source unit are varied depending on a color of a pixel indicated in the input video signal.

6. The liquid crystal display device of claim **1**, wherein among the red light source, the green light source, and the blue light source of the light source unit, a light source corresponding to grayscale levels of red, green, and blue having the minimum value of the input video signal is turned off, and a light source corresponding to grayscale levels of red, green, and blue having a value higher than the minimum value of the input video signal is turned on.

7. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates yellow, the red light source and the green light source are turned on, and the blue light source is turned off.

8. The liquid crystal display device of claim **1**, wherein in the case where the red, green, and blue grayscale levels indicated in the input video signal are higher than the minimum value, respectively, respective relative transmittances of the four or more sub-pixels in the liquid crystal panel exhibit a maximum value.

9. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates orange or yellowish green, the blue light source is turned off.

10. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates orange or yellowish green, respective relative intensities of the red light source and the green light source are higher than a relative intensity of the blue light source.

11. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates green, a relative intensity of the green light source is higher than a relative intensity of the red light source and a relative intensity of the blue light source.

12. The liquid crystal display device of claim **11**, wherein in a case where the input video signal indicates yellow, relative transmittances of the red sub-pixel, the green sub-pixel, and the yellow sub-pixel in the liquid crystal panel exhibit a maximum value.

13. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates green, the green light source is turned on, and relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

14. The liquid crystal display device of claim **1**, wherein in a case where the input video signal indicates green, the red light source and the green light source are turned on, and relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than relative transmittances of the red sub-pixel and the blue sub-pixel in the liquid crystal panel.

15. The liquid crystal display device of claim **1**, wherein
in a case where the red light source is turned on, a relative transmittance of the red sub-pixel in the liquid crystal panel exhibits a maximum value,
in a case where the green light source is turned on, a relative transmittance of the green sub-pixel in the liquid crystal panel exhibits a maximum value, and
in a case where the blue light source is turned on, a relative transmittance of the blue sub-pixel in the liquid crystal panel exhibits a maximum value.

16. The liquid crystal display device of claim **1**, wherein
in a case where the red light source is turned on and the green light source is turned off, relative transmittances of the red sub-pixel and the yellow sub-pixel are higher than a minimum value, and
in a case where the green light source is turned on and the red light source is turned off, relative transmittances of the green sub-pixel and the yellow sub-pixel are higher than a minimum value.

17. The liquid crystal display device of claim **1**, wherein the four or more sub-pixels further include a cyan sub-pixel.

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